Center for Climate Change and Sustainable Energy Policy

Central European University

Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Poland[C1]

Final report

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The 3CSEP Research Team

1 Technical summary

1.1 Background, aims and scope

Poland is approaching a decisive stage for the future of its energy system. The energy intensity of its economy is still significantly higher than the EU27 average: as shown by Eurostat data, Poland uses more than twice the energy a typical Member State needs to produce one unit of output (GDP). There is also an urgent need to upgrade Poland's energy system, primarily its electricity and district heating infrastructure; half of which is more than 30 years old and reaching the end of its lifespan. Substantial capital investments are required for the whole energy system. This includes developing new sources of energy (such as shale and other forms of unconventional gas, if their potential is confirmed) along with the infrastructure for carbon capture and storage – to accommodate the continued use of coal for electricity and heat production. However, in the long-term the country's traditional reliance on coal is unsustainable, due to environmental factors and because national production is already failing to meet domestic demand. In 2008, for the first time, Poland became a net importer of coal, and hard coal production is expected to decrease sharply by 2030 (2015 for lignite).

In addition, Poland is facing major challenges from the European economic crisis, despite its better performance compared to other Member States. This means struggling businesses, increasing unemployment and tightening budgets for social welfare spending and energy-related projects and subsidies.

In this context, buildings in Poland are key to both a robust, secure and socially attractive energy infrastructure upgrade. They also provide an alternative path to stronger economic growth. A more robust and cost-effective upgrade of Poland's energy infrastructure offers an avenue for alternative capital investments. This renewal can deliver large demand-side energy cost savings as opposed to an unsustainable and costly expansion and retrofit of the supply-side capacity. The sustainable demand-side path also comes with significantly more jobs per euro invested, increased social welfare for households, reduced need for energy-related (direct or indirect) subsidies; sustains or creates local businesses, including rural areas; eradicates fuel poverty; and reduces the needs for infrastructure investments, especially with regard to the district heating network.

Buildings in Poland are key to the climate challenge: they are responsible for over 25% of its final energy consumption and constitute the second most demanding end-use sector of the country after industry. This is linked to the poor thermal performance of its building stock, which is among the ten less inefficient EU27 nations as measured by the specific energy consumption for space heating in the households sector. However, in a CEE context, Poland stands out as a relatively good performer in the field of energy efficiency in residential buildings, as evidenced by the evolution of its ODEX energy efficiency index of households for space heating in the last ten years. This is the likely result of more than a decade of implementation of the Thermo-Modernization Programme, which since 1999 has retrofitted more than 20% of the Polish buildings stock delivering savings in the region of the 30% of the energy consumption before retrofit. Though substantial when compared with the achievements of energy efficiency programmes in other countries of the region, if such shallow retrofits keep on being implemented a large fraction of the energy and emissions saving potential of the Polish building stock will be *locked-in* and hamper the compliance of long-term emission reduction targets (50% to 85% of the year 2000 global carbon emissions by 2050, as established by the IPCC in its last assessment report). Much more ambitious climate policies – including energy efficiency programmes for the building sector – are thus required.

On the other hand, retrofitting the Polish building stock with state-of-the-art technologies and know-how (e.g., passive house standard or similar) not only can largely reduce the energy costs of building owners and users and significantly reduce sectoral and national greenhouse gas emissions. It can also advance several other important social, political and economic policy agendas, namely reducing the energy dependency from imported fuels (mostly natural gas from the former Soviet Union), alleviating and eventually eliminating fuel poverty, improving the air quality and public health conditions of urban settlements, improving the fiscal balance of the State budget and increasing the market value of its real estate. Some this aspects have particular significance in the case of Poland, which is one of the few coal-dependent economies of the world – coal is the probably the most polluting of all fossil fuels currently in use – and where fuel poverty rates, as in many other CEE nations, tend to be higher than in Western Europe (e.g., as an average for the period 2005-2010, every fifith Pole declared to be unable to afford to keep his or her home adequately warm in the cold season).

An especially important co-benefit of a large and deep retrofit of the Polish building stock is the net employment creation effect of building renovations, particularly as Poland has one of the lowest employment rates of the EU27 (59.3% as an average for 2009-2010). In fact, since the Lisbon Strategy for Growth and Jobs has included as key targets the need to achieve a 75% employment rate (for the 20 to 64 population) and to increase the energy efficiency of the EU economies by 2020, clear synergies between climate and policy goals exist. As this study argues, they can be realized through the deep retrofitting of Polish buildings.

The goal of the present research is thus to gauge the net employment impacts of a large-scale deep building energy-efficiency renovation programme in Poland. The deep renovation of Poland's residential and public buildings – beyond other previously mentioned benefits such as reducing fuel poverty, improving the air quality of urban areas and improving energy security – is expected to have a consistent positive impact on employment levels:

- Directly, by the creation of many new jobs in the construction industry;
- Indirectly, on all the sectors that supply materials and services to the construction industry itself;
- In addition, the savings caused by the reduction in energy consumption, plus the additional consumption fuelled by the wages of the additional jobs created, will increase the disposable income of the families; income that, when spent, will generate additional induced benefits to employment. These are referred to as *induced* effects.

These impacts are expected to be larger than the jobs lost in the energy supply and its production chain-related sectors resulting of the reduced energy consumption (see Błąd! Nie można odnaleźć źródła odsyłacza. showing the chain of effects on employment of the proposed intervention).

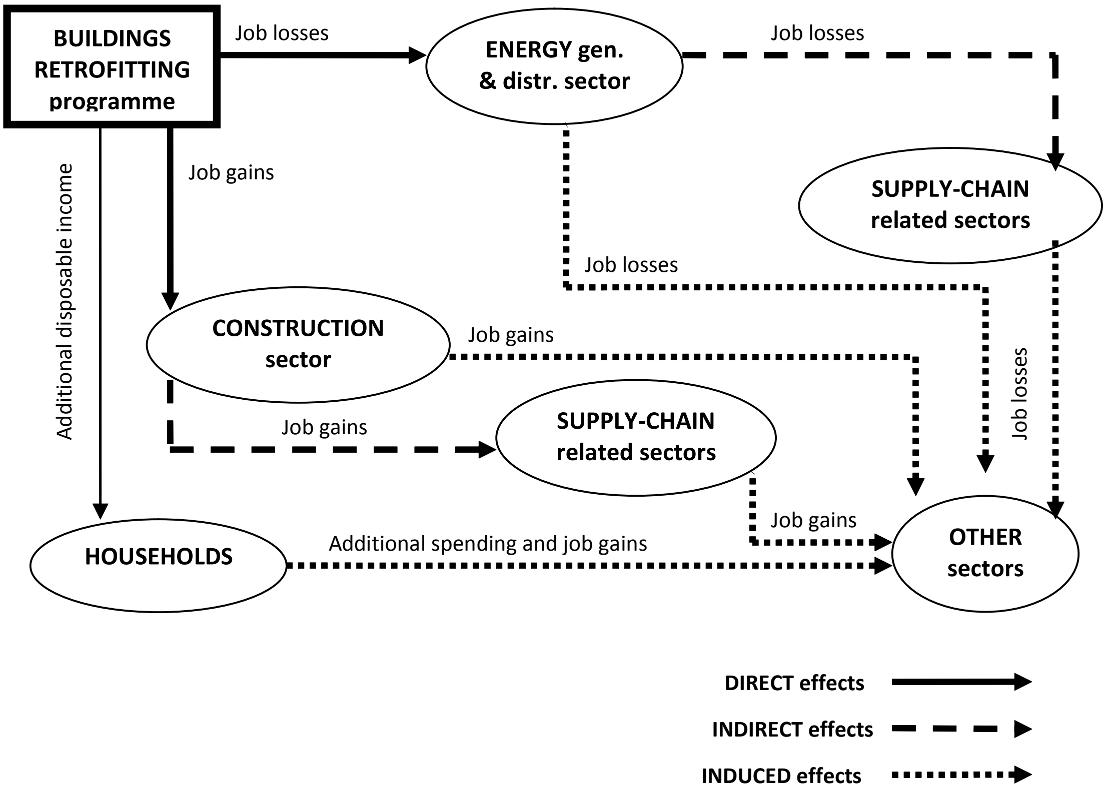

Figure 1-1: Chain of effects on employment of the proposed intervention

This report has been produced in the framework of the European Climate Foundation (ECF) Energy Efficiency programme, in particular the "energy efficiency in buildings" strategic initiative pursued by the ECF. It draws upon the buildings and employment model and methodology used for the previous study also conducted by 3CSEP on behalf of ECF in Hungary in spring 2010 (Ürge-Vorsatz et al., 2010).

1.2 Description of the renovation scenarios assessed in this study

Since the employment impacts are determined by the intensity, scale and schedule of the renovation programme, the study has investigated the impact of specific renovation scenarios. The scenarios depend mainly on the type or depth of retrofits included in the programme and the dynamic of renovation assumed. **Table 1-1** summarises their main characteristics..

Name	Scenario	Retrofit rate	Type of retrofits	Forecasted completion
S-BASE	**Baseline** scenario with current subsidies	**3% of the non-renovated stock in 2010** - 25 million square meters or 310,000 dwellings per year	*Business-as-usual* thermo-retrofits	33 years

S-DEEP1	**Deep** retrofit with slow implementation rate	**1.5%** - 16 million square meters or 195,000 dwellings per year	Deep retrofits	68 years
S-DEEP2	**Deep** retrofit with medium implementation rate	**2.5%** - 26 million square meters or 320,000 dwellings per year	Deep retrofits	42 years
S-DEEP3	**Deep** retrofit with fast implementation rate	**3.5%** - 36 million square meters or 450,000 dwellings per year	Deep retrofits	31 years
S-SUB	**Suboptimal** retrofit with medium implementation rate	**3% of the non-renovated stock in 2010** - 25 million square meters or 310,000 dwellings per year	Suboptimal retrofits	33 years

Table 1-1: Retrofit programme scenarios

The research focuses on existing residential and public buildings, as those are the two sectors where most policy intervention/public support is warranted and where the highest social and political benefits can be found. New buildings and commercial and other types of buildings are outside the scope of the study.

The study emphasises scenarios that support *deep* retrofits, which bring the buildings as close to passive house standards (i.e. a consumption of 15 kWh/m^2/year for heating) as realistically and economically feasible (50 kWh/m^2/year, including hot water, in the case of Poland), but examines another scenario delivering less ambition energy savings (*S-SUB*) for comparative purposes too. The reason for this choice is the very substantial potential *lock-in* effect resulting from so-called *suboptimal* renovations, which would hinder the possibility of realising the potential of the Polish building stock and would severely jeopardise the compliance of Poland's ability to attain the ambitious GHG emission reduction long-term targets envisioned by 2050. This stresses the importance of channelling economic resources in catalysing a renovation scenario that keeps long-term climate (and social) interests in the foreground rather than *cherry-picks* in a short-term economic optimisation framework.

The Polish building stock. **Table 1-2Table** 1-2: Summary of characteristics of the residential building stock

and Table 1-3 summarize the characteristics of the Polish residential and public building stocks, together with the assumptions of specific space and water heating energy requirements. The fraction of dwelling floor area heated was assumed to remain the same before and after renovation (75%).

Residential units are the most important sub-set of the total stock considered because they take 84% of the total floor area. Public buildings contribute to a lesser extent because they represent just 16% of the total floor area considered.

1.3 Methodology and key assumptions

The literature acknowledges several methodological approaches to analyse the impact of climate interventions on the labour market: direct estimates based on the up-scaling of case studies, Input-Output (I/O) analysis, computable general equilibrium model (CGEM) analysis and transfer of results from previous studies.

Among these, Input-Output analysis is the most widely utilised methodology employed for forecasting the direct, indirect and induced employment impacts of changes in the economy, including energy efficiency interventions. Input-Output tables allow the analysis of changes in the economic activity of all sectors generated by an intervention. Provided the labour intensity of each sector, estimates of the net employment effects (the balance of jobs created and destroyed) can be derived.

This study uses a mixed approach to calculate the employment impact of energy-efficient retrofits. In order to estimate the direct effects in the construction sector, data from a number of case studies was collected and up-scaled; for indirect and induced effects, the Input-Output method was applied. This mixed approach was chosen because Input-Output analysis was deemed too crude to estimate direct effects (i.e., the labour intensity of renovation activities turned out to be, according to the case study-based data collected, substantially higher than the general construction sector labour intensity). Thus, it was concluded that a bottom-up approach using a sub-sector specific employment multiplier for the building renovation industry would ensure a more realistic estimate of direct employment effects.

The retrofit programme is assumed to start in 2011 in all scenarios; impacts have been evaluated as a function of time, with special focus on analysis for the year 2020, a key year in the EU context (particularly in climate and employment). The report also projected the employment impacts in the medium and long term (up to 2080).

For the purposes of the study, all buildings of the Polish residential and public stock have been divided into classes according to they year of construction (from before 1918 to 1989-2010), size/shape (single-family/single-storey vs. multi-family/multi-storey) and use (residential vs. public). For each class and each scenario, a collection of data has been derived (whenever possible) from case studies and literature: labour required to perform renovations (divided by skill level), retrofit costs and energy savings obtained[C2].

RESIDENTIAL BUILDINGS	SINGLE FAMILY					MULTI-FAMILY				
	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010
Fraction of Total Building Floor Area	4%	5%	10%	16%	12%	3%	4%	8%	13%	9%
Specific Energy Requirement (kWh/m^2/a)	456	380	347	302	262	322	258	228	203	182
After Renovation – *S-BASE* Scenario										
Specific Energy Requirement (kWh/m^2/a)	319	266	243	211	184	226	180	159	142	127
After Renovation - *S-DEEP* Scenario(s)										
Specific Energy Requirement (kWh/m^2/a)	50	50	50	50	50	50	50	50	50	50
After renovation - *S-SUB* Scenario										
Specific Energy Requirement (kWh/m^2/a)	228	190	173	151	131	161	129	114	101	91

Table 1-2: Summary of characteristics of the residential building stock

PUBLIC BUILDINGS	SINGLE STOREY					MULTI STOREY				
	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010
Fraction of Total Building Floor Area	0.1%	0.1%	0.3%	0.4%	0.3%	1.2%	1.7%	3.1%	5.0%	3.7%
Specific Energy Requirement (kWh/m^2/a)	344	286	261	227	198	243	194	172	153	137
After Renovation – *S-BASE* Scenario										
Specific Energy Requirement (kWh/m^2/a)	241	200	183	159	138	170	136	120	107	96
After Renovation - *S-DEEP* Scenario(s)										
Specific Energy Requirement (kWh/m^2/a)	50	50	50	50	50	50	50	50	50	50
After renovation - *S-SUB* Scenario										
Specific Energy Requirement (kWh/m^2/a)	172	143	131	114	99	121	97	86	76	69

Table 1-3: Summary of characteristics of the public building stock

The labour requirements have been up-scaled to the total residential and public building stock, in order to obtain the direct effects of each scenario on the construction sector.

For the direct negative effects in the energy sector, as well as for the positive indirect and induced effects generated by the renovation programme, total renovation investment costs and energy savings were calculated. These represent the increase of demand in the construction sector and the decrease in energy demand. Those values have then been entered into Input-Output tables, returning as a result the indirect and induced changes in output for every sector of the economy. By multiplying these changes in output by the labour intensity in each sector (i.e., the number of Full-Time Equivalent, or FTE, workers employed per unit of output in each industry), the indirect and induced employment effects for all sectors have been determined.

The induced effects generated by the energy savings accrued by households (or public building managers) have also been calculated by entering the value for the additional disposable income into the Input-Output tables. However, that value depends on the structure of financing used to pay for the investments. This study assumed a *pay-as-you-save* scheme where 80% of the energy savings go towards the repayment of the loan, while the rest is available as additional disposable income. When the loan is completely repaid, all the savings become additional disposable income, though this assumption was not incorporated to the model to avoid further complexity.

Since there is practically no experience with deep renovations in Poland (and little worldwide), the model has incorporated a technology (or here rather know-how) learning parameter. A rate of decrease of deep renovation costs based on the learning factor has been integrated in the research. The reason for this is that in *S-DEEP* scenarios, firms and individuals are expected to improve their skills related to energy-efficient retrofit technologies and know-how; at the same time, with the increase in demand building materials quickly become mass-produced, thus generating price reductions due to economies of scale and positive learning effects. An additional assumption is that costs for baseline and suboptimal renovations would remain fixed throughout the period analysed, because the technologies for these types of retrofits is already mature and cannot benefit from significant reductions due to learning factors.

The model also allowed performing a sensitivity analysis to two key parameters – the previously mentioned learning factor of deep renovation scenarios and the costs of deep renovation at the beginning of the programme (2011) – to see the extent to which these more uncertain parameters influence the final results.

1.4 *Main findings*

1.4.1 Energy and CO_2 savings, investments costs and energy saving benefits, energy security benefits

Energy savings. All renovation scenarios – in particular those involving deep retrofits – generate energy savings. **Figure 1-2** shows the evolution of the final heating energy use for the whole building stock in each scenario. *S-DEEP* programmes deliver at the end of its implementation 84% savings in the aggregated space and water heating consumed by Polish buildings in 2010, whereas a suboptimal programme would go up to 42% of energy savings and *business-as-usual* retrofits (i.e., a continued implementation of the existing Thermo-modernisation programme) would achieve just 25% (note that the latter two scenarios only act on the 80% of the building stock that has not yet been benefited from the programme).

Figure 1-3 to **Figure 1-7** show the evolution of energy use by the assumed categories of buildings in the Polish building stock until 2080, for all scenarios. The categories that comprise the largest shares of energy savings are residential single-family buildings built in 1971-1988 and residential multi-family buildings built in 1971-1998 and 1989-2010.

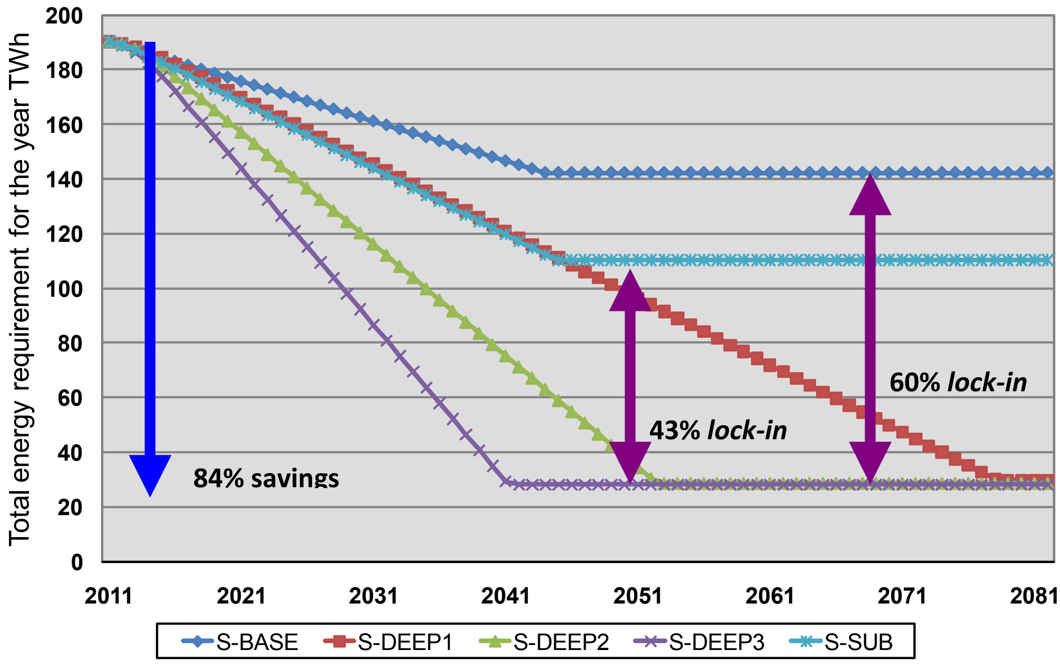

Figure 1-2: Annual space and water energy requirement (TWh/year) of the existing Polish building stock for all scenarios considered

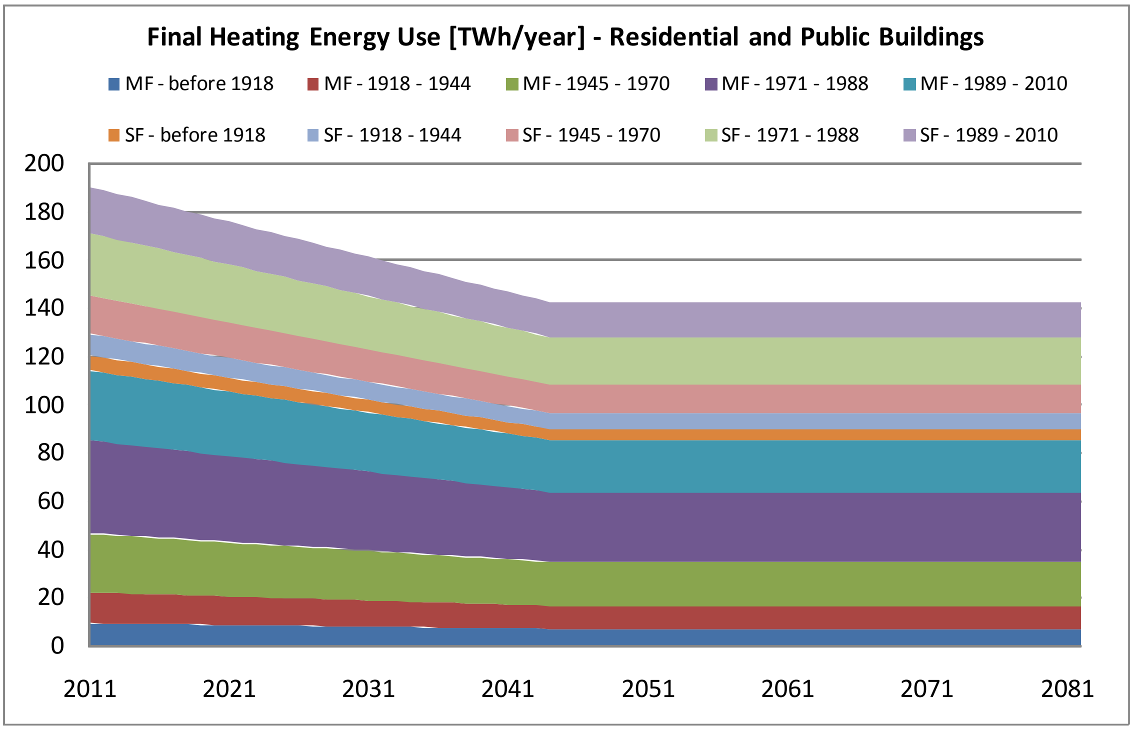

Figure 1-3: Annual space and water heating energy use (TWh/year), by building categories - *S-BASE* scenario

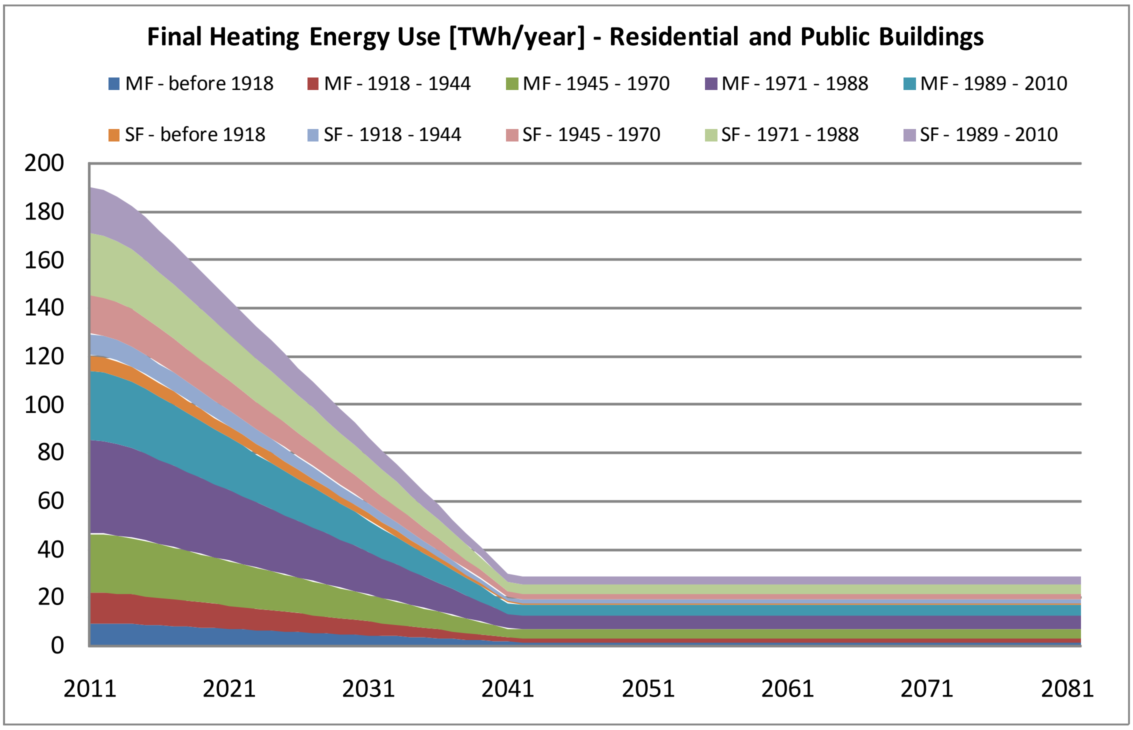

Figure 1-4: Annual space and water heating energy use (TWh/year), by building categories - *S-DEEP3* scenario

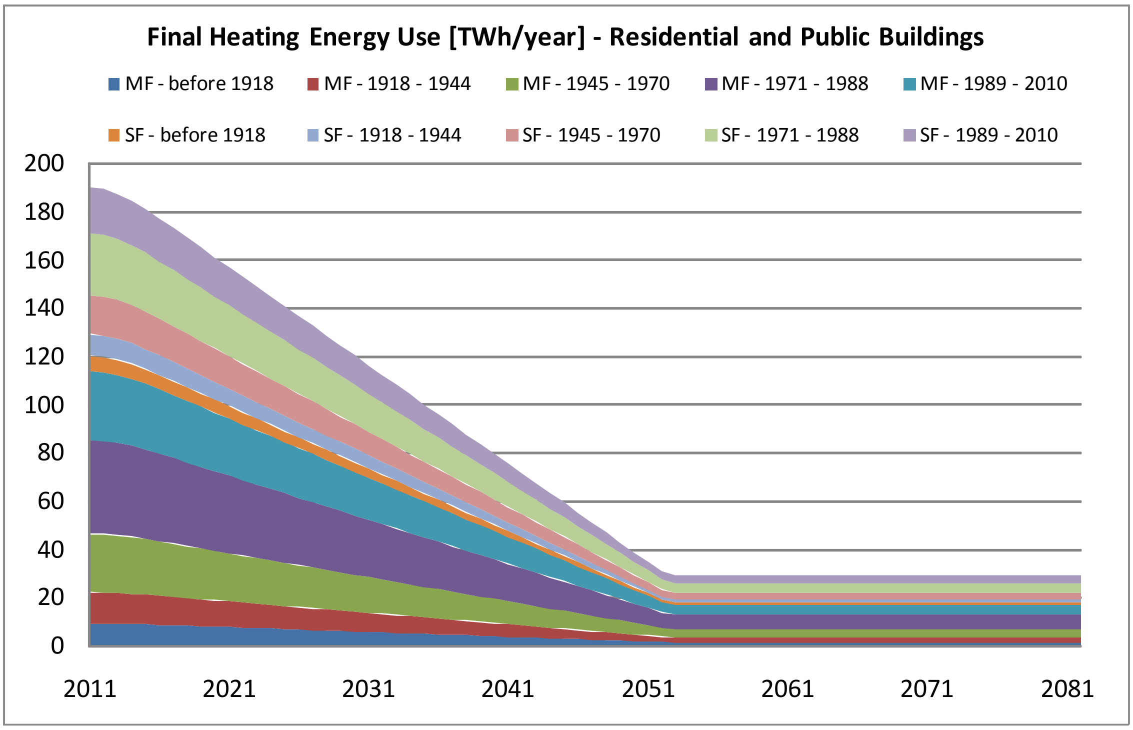

Figure 1-5: Annual space and water heating energy use (TWh/year), by building categories - *S-DEEP2* scenario

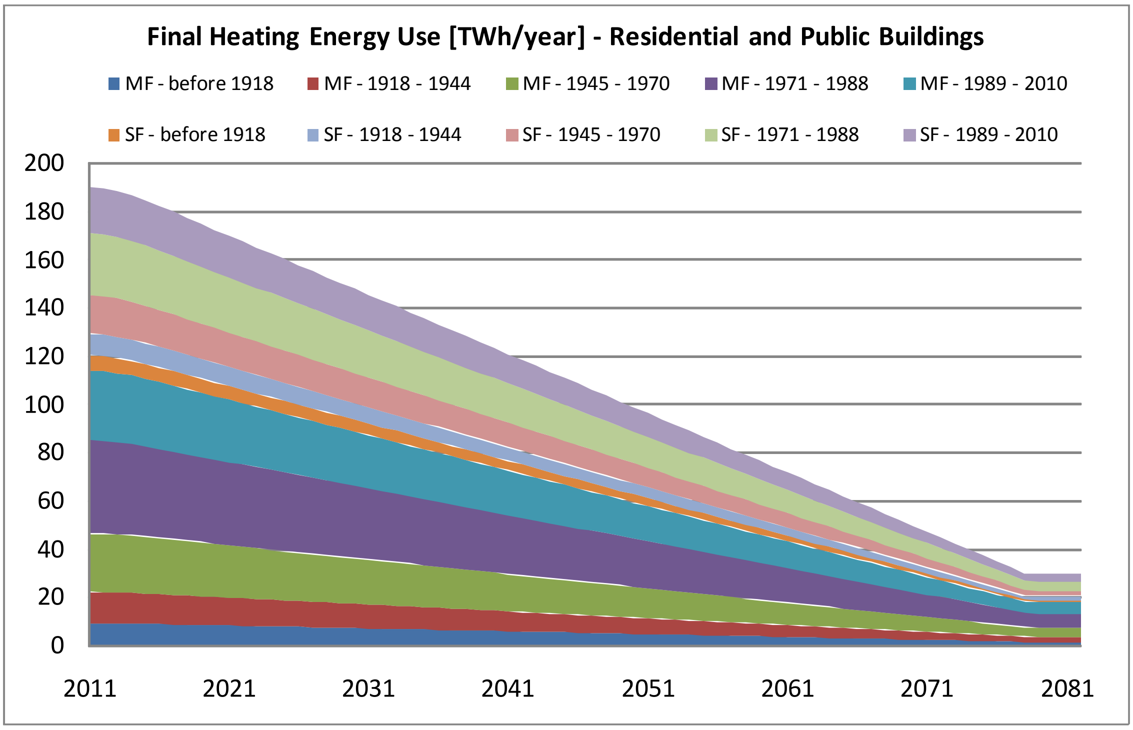

Figure 1-6: Annual space and water heating energy use (TWh/year), by building categories - *S-DEEP1* scenario

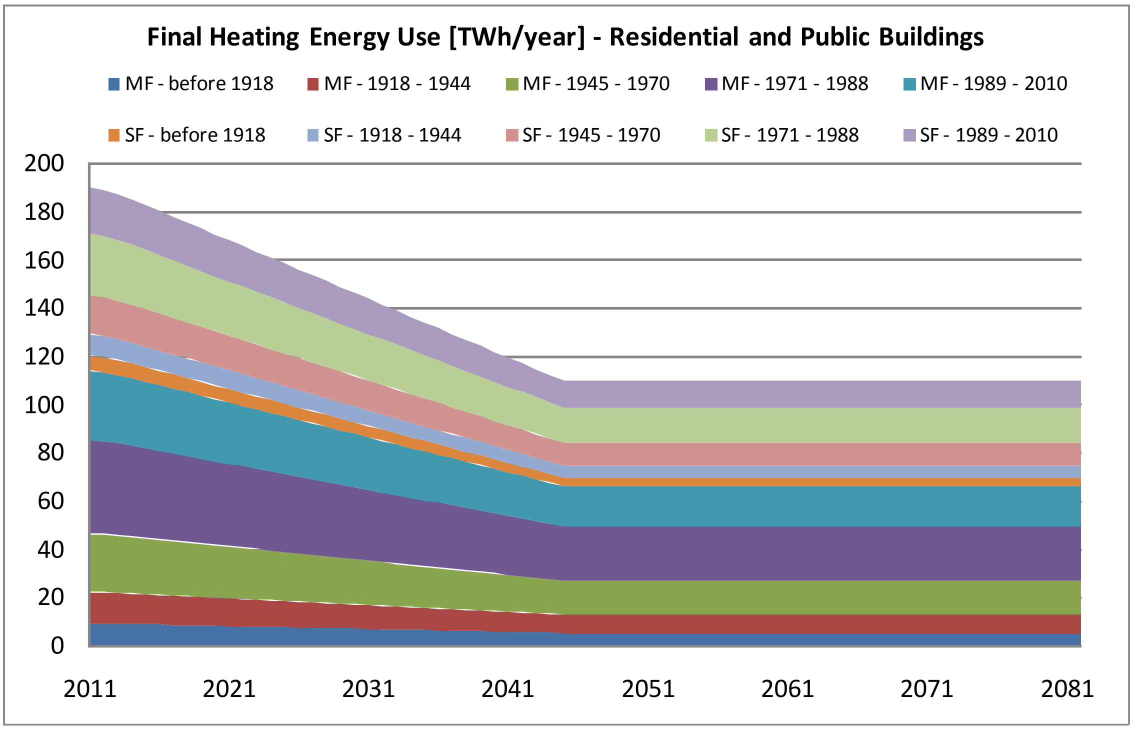

Figure 1-7: Annual space and water heating energy use (TWh/year), by building categories - *S-SUB* scenario

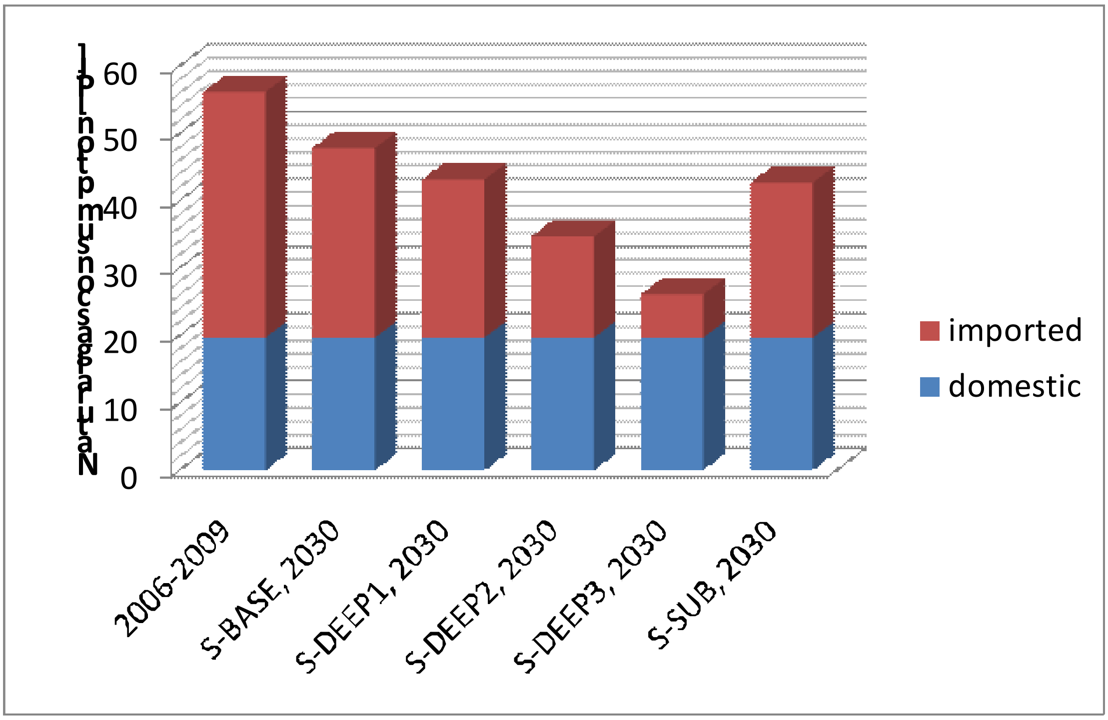

Figure 1-8: Buildings-related natural gas consumption in the year 2030, by retrofit scenarios

Energy security. Even though natural gas only supplies 8.2% of the heat consumed by the country's building stock, a large fraction of it (69%) is imported. The renovation programmes analyzed would therefore allow Poland to significantly reduce its natural gas imports and thereby improve its energy security. Błąd! Nie można odnaleźć źródła odsyłacza. illustrates the amount of natural gas that would be consumed by Polish buildings in 2030 under each renovation scenario, including both the natural gas used for end-use heating and consumed by district heating plants. By 2030, natural gas savings would range from 21% (*S-BASE*) to 77% (*S-DEEP3*) of Poland's buildings-related natural gas imports (taking as a reference the average imports for the 2006-2009 period).

Carbon savings. The amount of avoided CO_2 emissions in each scenario depends on the energy savings and on the CO_2 emission factors of the energy carriers used for space heating. **Figure 1-10** to **Figure 1-14** illustrate the reduction in CO_2 emissions from the entire Polish building sector through 2080 in the different scenarios and by building types. **Figure 1-9** depicts a summary view of the total decrease in CO_2 emissions for each scenario, which follow, as expected, the same trend as energy savings. It also indicates the extent of CO_2 emissions *locked-in* by the implementation of a suboptimal or base (i.e. Thermo-modernization) renovation programme.

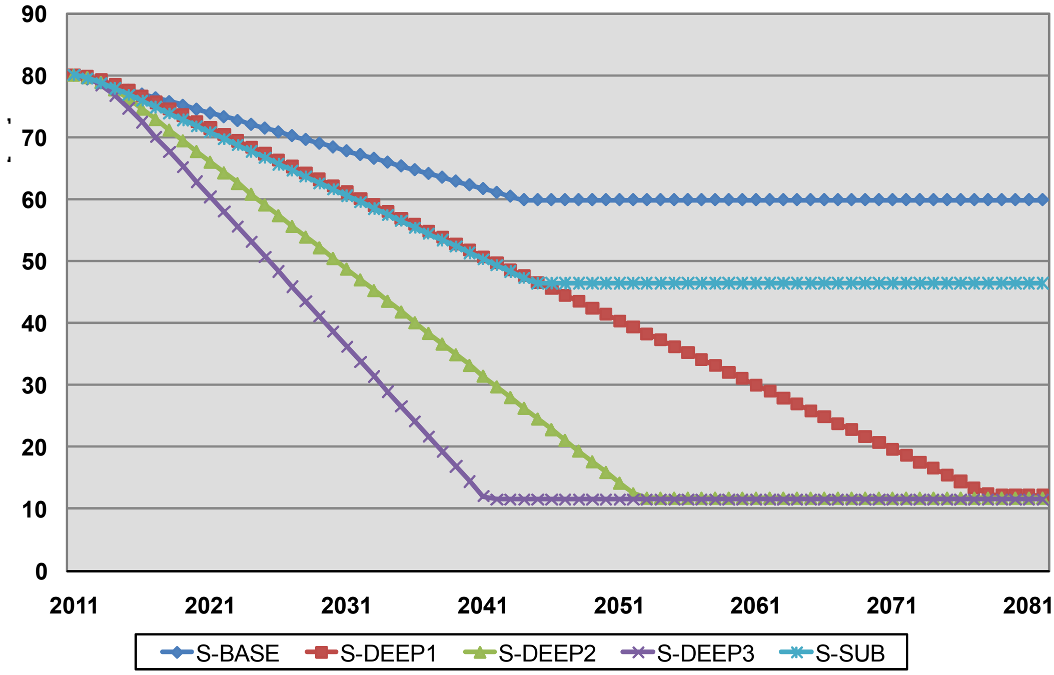

Figure 1-9: Annual CO_2 emissions (Mt/year) for space and water heating of the Polish building stock, for all scenarios considered

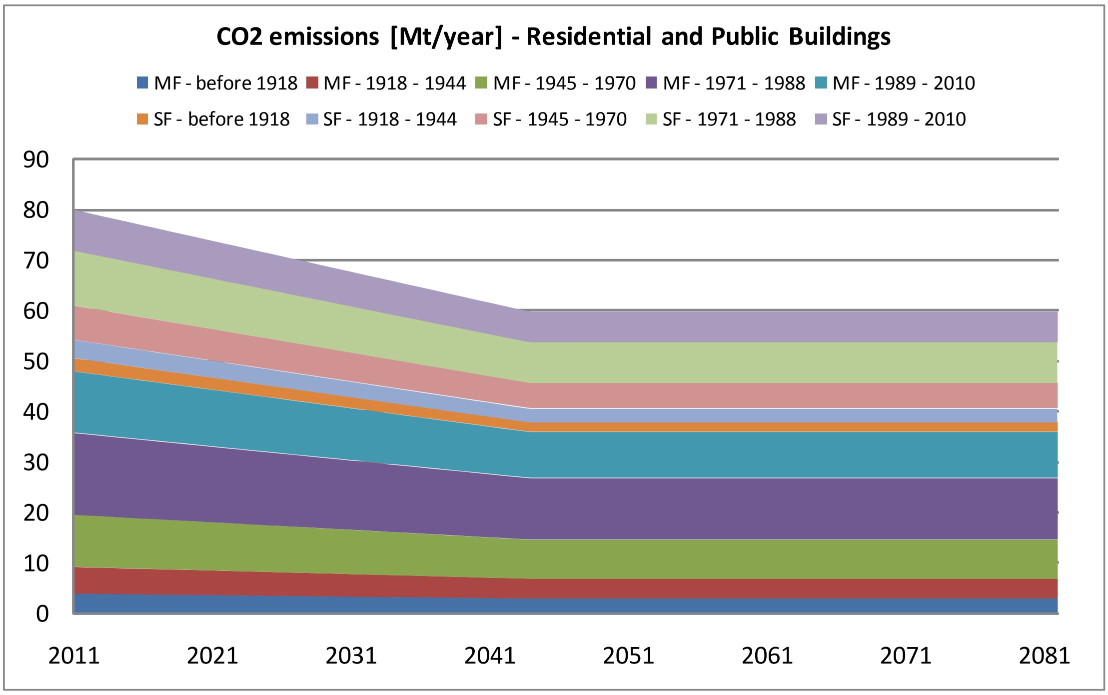

Figure 1-10: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-BASE* scenario

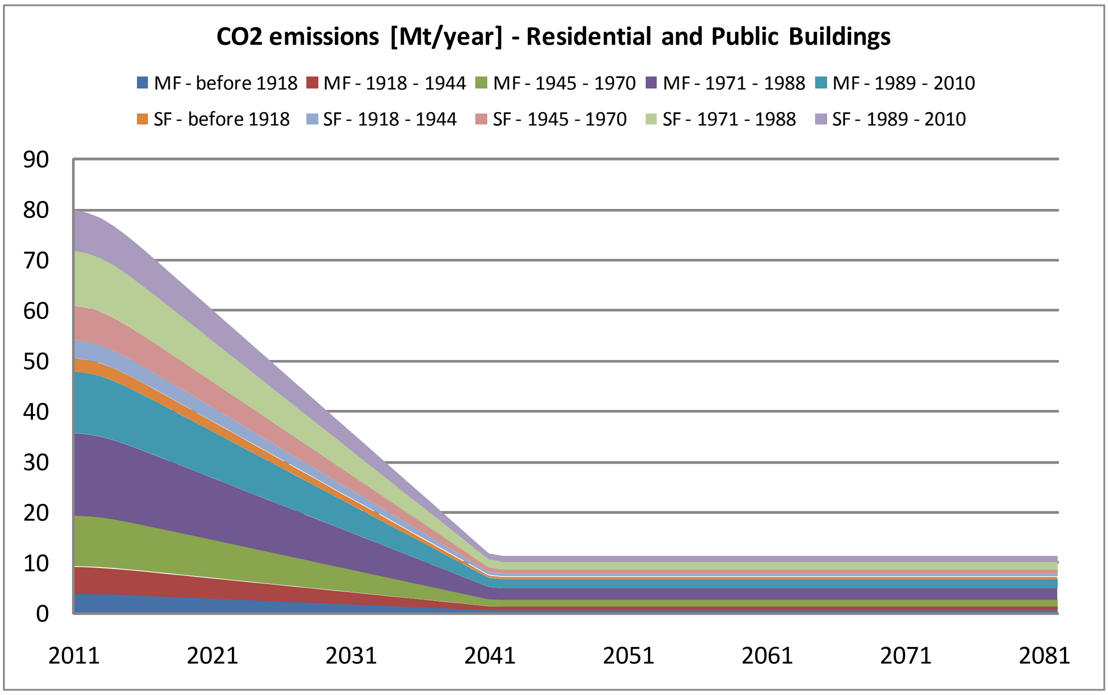

Figure 1-11: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-DEEP3* scenario

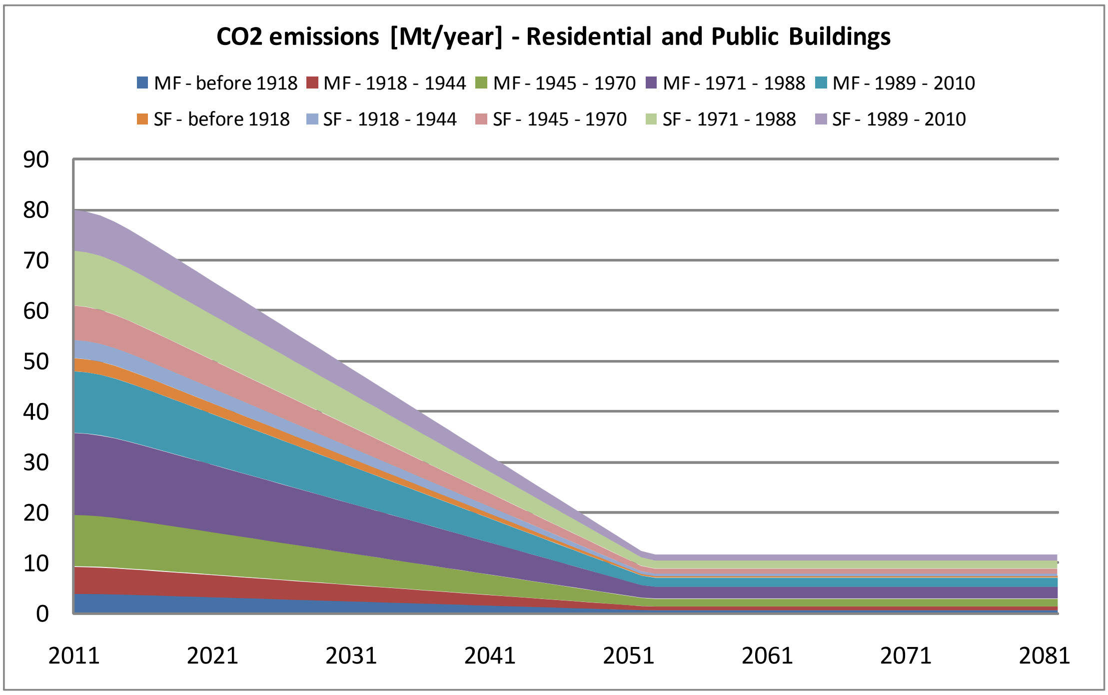

Figure 1-12: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-DEEP2* scenario

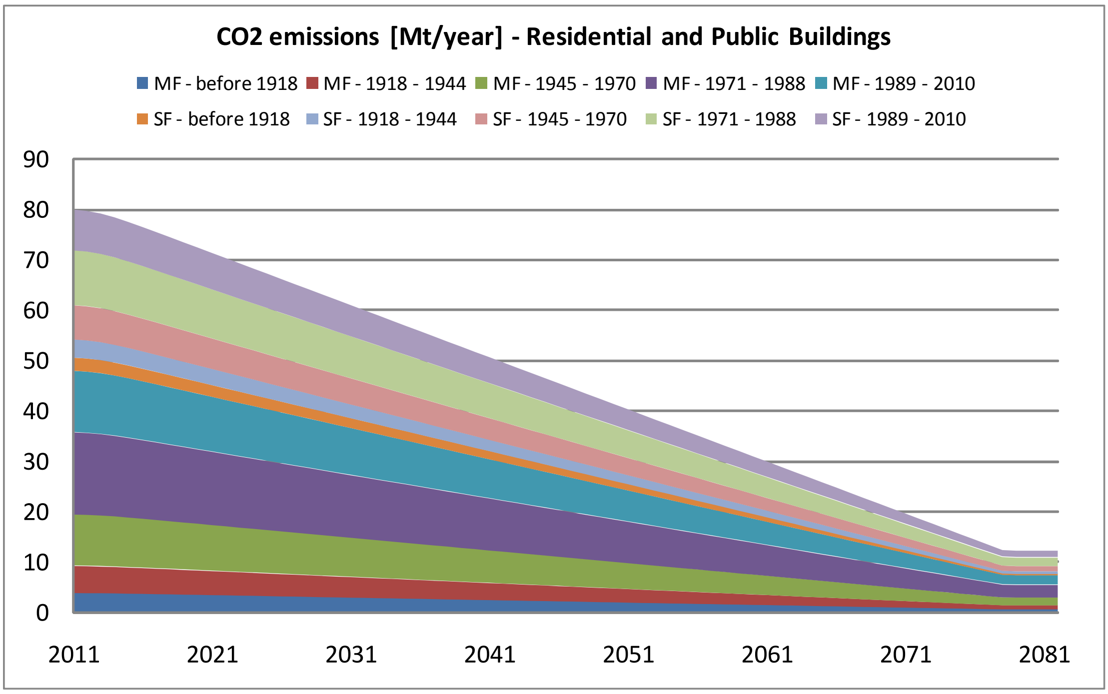

Figure 1-13: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-DEEP1* scenario

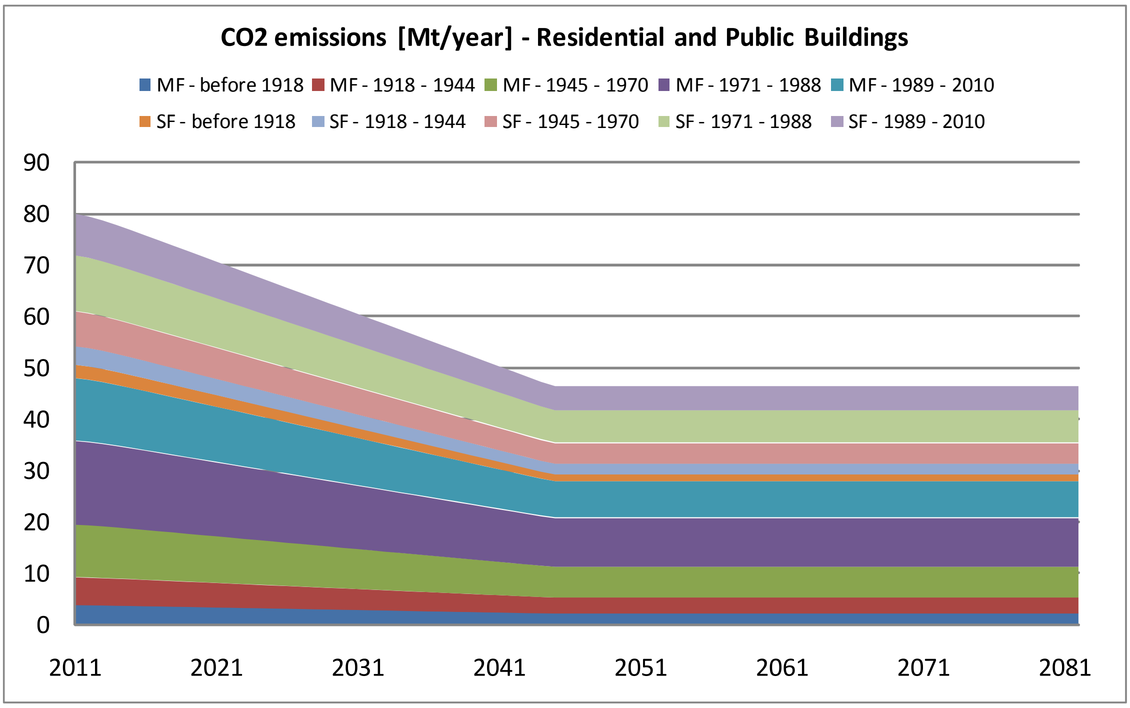

Figure 1-14: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-SUB* scenario

Investment costs and energy saving benefits. The estimates elaborated in this research show that the retrofit programmes considered will involve a considerable amount of investments, but will also generate a growing amount of energy expenditure savings. **Table 1-4** shows the investment needs in the year 2020 and the energy cost savings generated in 2020 by all dwellings renovated up to that year for all scenarios, while **Figure 1-15** and **Figure 1-16** visualise the trend for these two values for each scenario until the end of the programme and beyond. The values take into account a ramp-up period of five years, which the research assumed will be required by the construction industry to respond to the additional demand. All estimates have been calculated in Euros 2010, to discard inflation effects.

Annual investments are quite significant. For the deep scenario, they range between 3.9 and 8.4 billion EUR2010 per year (*S-DEEP3*) and 1.3 to 3.6 billion EUR2010 per year (*S-DEEP1*), whereas *business-as-usual* and suboptimal retrofits would require according to the model a constant investment of around 1 and 2 billion EUR2010 respectively. For comparison, the Polish national budget expenditures in 2009 totaled approximately 75 billion EUR. *S-DEEP3* scenario's annual investment costs would then approach 10% of the national budget (5% for *S-DEEP1*, 8% for *S-DEEP2*, and 3% for *S-SUB*).

As for energy saving benefits, they are clearly higher for the deep renovation scenarios and more modest in the suboptimal and baseline scenarios. **Figure 1-15** and **Figure 1-16** illustrate that the annual investment needs in the renovation programmes are initially higher than the annual energy saving benefits obtained at first through the reduction of energy consumption; however, the energy savings increase fast (as every year, the savings from the dwellings retrofitted in the current year are added to the savings from all the dwellings previously renovated) and eventually – by the year 2035 – outstrip the investment costs by far, especially for deep renovation scenarios.

	S-DEEP3	S-DEEP2	S-DEEP1	S-SUB
Annual investment costs by 2020, in million Euros 2010	6,995	4,997	2,999	2,154
Annual energy saving benefits in 2020, in million Euros 2010	1,305	932	572	643

Table 1-4: Annual investment costs and energy saving benefits in 2020

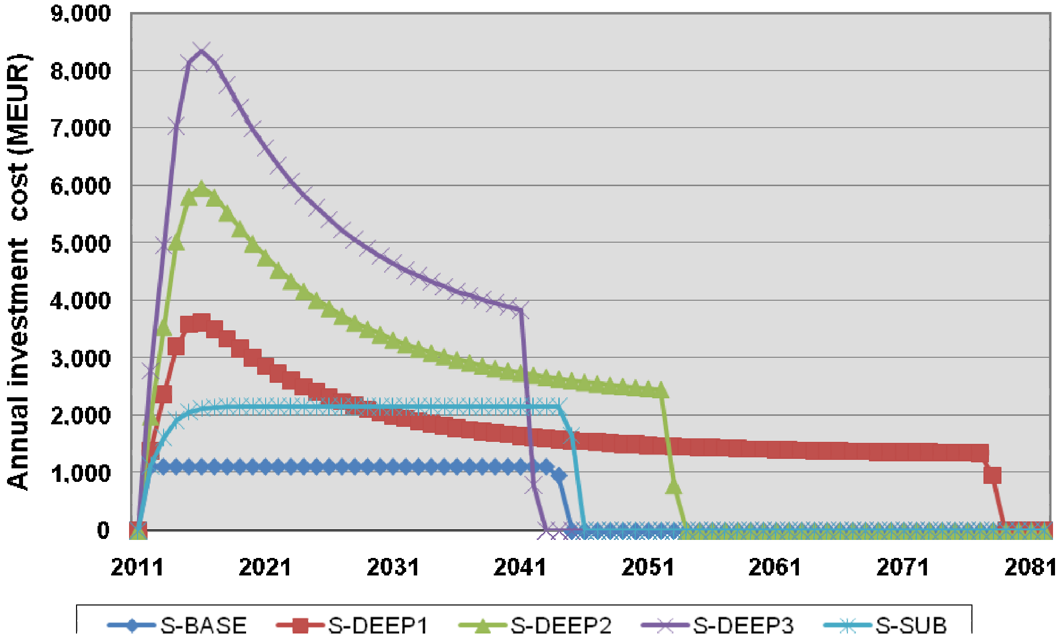

Figure 1-15: Annual investment costs for all renovation scenarios

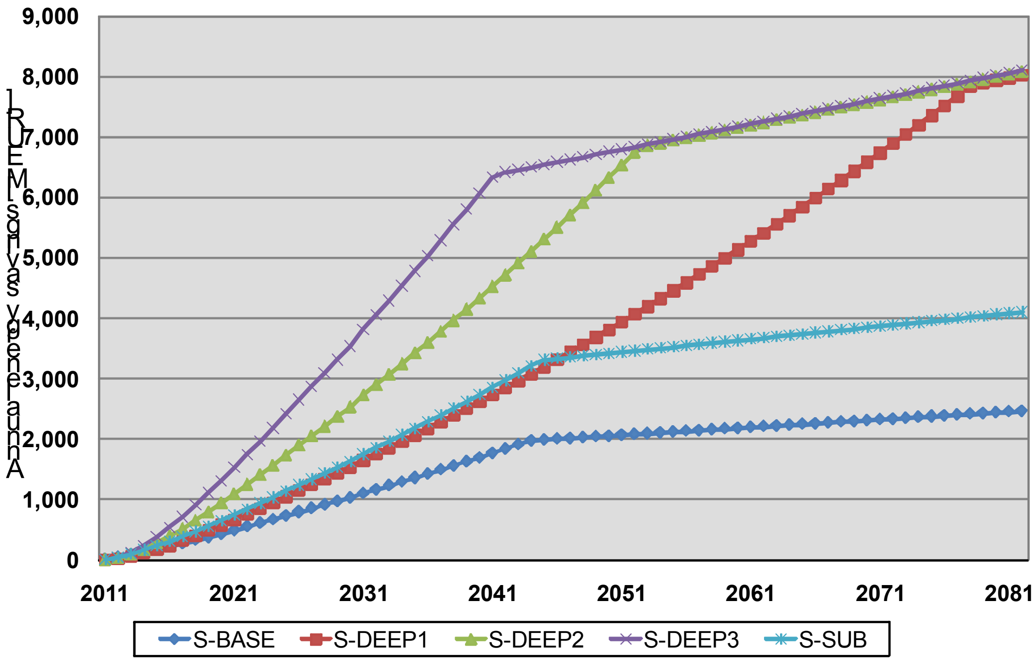

Figure 1-16: Annual energy saving benefits generated by all scenarios

Finally, total cumulative investment needs were calculated by adding all annual programme investments, and then compared to the total cumulative energy cost savings. **Table 1-5** summarizes these results (undiscounted) for the years 2025, 2050 and 2080, the latter being the year in which all scenarios are completed. Undiscounted total savings have far outstripped undiscounted total investment costs by this time in all scenarios.

Cumulative investments vs. cumulative savings (undiscounted, Billion Euros 2010)		**2025**	**2050**	**2080**
S-DEEP1	Cumulative investment costs	-40	-85	-124
	Cumulative energy saving benefits	7	67	246
	Undiscounted net benefits	**-34**	**-18**	**122**
S-DEEP2	Cumulative investment costs	-66	-140	-146
	Cumulative energy saving benefits	11	111	332
	Undiscounted net benefits	**-55**	**-29**	**186**
S-DEEP3	Cumulative investment costs	-92	-164	-164
	Cumulative energy saving benefits	15	145	367
	Undiscounted net benefits	**-77**	**-19**	**203**
S-SUB	Cumulative investment costs	-28	-71	-71
	Cumulative energy saving benefits	8	69	182
	Undiscounted net benefits	**-21**	**-2**	**111**

Table 1-5: Cumulative investment needs compared with cumulative energy cost savings (undiscounted)

From a total investment cost perspective, a more gradual implementation of a deep renovation programme is preferred. Due to the relative inexperience with deep renovation know-how and technologies, initially these will undoubtedly be more expensive than after a learning period when experience accumulates and more mature markets and competitive supply chains are established. Thus a more aggressive renovation programme (i.e., 450,000 units per year, *S-DEEP3*) will result in higher total costs – 164 billion Euros, which compares to 146 and 124 billion Euros of *S-DEEP1* and *S-DEEP2* scenarios. These costs can be shared by building owners, the government and even utility companies, with additional sources of capital like the sale of CO_2 quota and revenues from EU ETS auctions, helping to meet the financing needs of the program (see financing options in **Section 8.5**). Besides, a careful implementation can minimize total costs, i.e., building types with a lower cost per sqm. (e.g., multi-family units built in 1945-1970) can be retrofitted first and then proceed with more expensive typologies (e.g., single-family units from 1971-1988) at later stages, once the learning factor has effectively reduced the cost of retrofits.

On the benefits' side, a more ambitious implementation rate results in a faster harvesting of energy saving benefits: by 2080, the total accumulated undiscounted net benefits of *S-DEEP3* amount to 203 billion Euros, whereas *S-DEEP2* and *S-DEEP1* generate 186 and 122 billion Euros each. All in all, these results indicate that in the long-term, the energy saving benefits accrued through retrofits surpass investment costs, and that deep retrofits are preferable to suboptimal from an undiscounted private costs vs. benefits perspective. Among deep scenarios, a more ambitious retrofit rate delivers more undiscounted net benefits and is a preferable alternative as long as the potential negative effects described in

Sections 7.3.27.3.3 and **9.2.2** (e.g., destruction of the previously created employment because of the learning factor, bottlenecks in the supply of labour, capital and materials) are dealt with. Because of the existing trade-offs, *S-DEEP2* scenario can be suggested as a rate of retrofit that maximizes net benefits without compromising the feasibility of the programme or creating imbalances in the labour and other markets affected by the retrofits.

A careful of review of these economic results, which are less appealing than the ones obtained for the preceding Hungarian study[1], concluded that that among all the model parameters the main difference has to do the with the fuel mix: most Polish buildings use coal (either directly or as district heating), a cheaper fuel than natural gas, for heating. This is the key factor which makes deep retrofits look relatively less attractive than suboptimal ones in Poland. If Poland had substituted coal as a heat source by natural gas (as Hungary did in the 1990s), net economic benefits would be achieved much earlier (before 2050). This conclusion, obtained as a *by-product* of the comparison of both studies, indicates that a coal-based economy is less likely to adopt energy efficiency measures because it has fewer incentives to do so.

However, when compared to alternative mitigation strategies, building retrofits are a more cost-effective solution. That way, if the amount of carbon emissions avoided by the retrofits until 2080 were to be mitigated in power plants through CCS (carbon capture and storage, a relevant alternative mitigation option according to Poland's energy strategy), this would be achieved at a higher cost. As shown in **Table 1-6** and **Figure 1-17** in the long-term CCS results in significant net costs whereas building retrofits deliver substantial net benefits. It must also be noted that this technology – unlike energy efficiency retrofits – increases the production cost of coal-based electricity between 20 to 90% and does not bring as many co-benefits.

Alternative CCS mitigation costs (undiscounted, Billion Euros 2010)		**2025**	**2050**	**2080**
S-DEEP1	High-bound (Oxy-combustion plant)	-2	-15	-47
	Low-bound (IGCC plant)	-2	-12	-37
S-DEEP2	High-bound (Oxy-combustion plant)	-4	-25	-64
	Low-bound (IGCC plant)	-3	-20	-51
S-DEEP3	High-bound (Oxy-combustion plant)	-5	-33	-72
	Low-bound (IGCC plant)	-4	-26	-57
S-SUB	High-bound (Oxy-combustion plant)	-3	-16	-35
	Low-bound (IGCC plant)	-2	-13	-27

Table 1-6: Cost of mitigating the same amount of carbon emissions as scenarios through carbon capture and storage (CCS).

[1] Ürge-Vorsatz, D., Arena, D., Tirado Herrero, S., Butcher, A.C., 2010. Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary. 3CSEP / Central European University Budapest, Hungary.

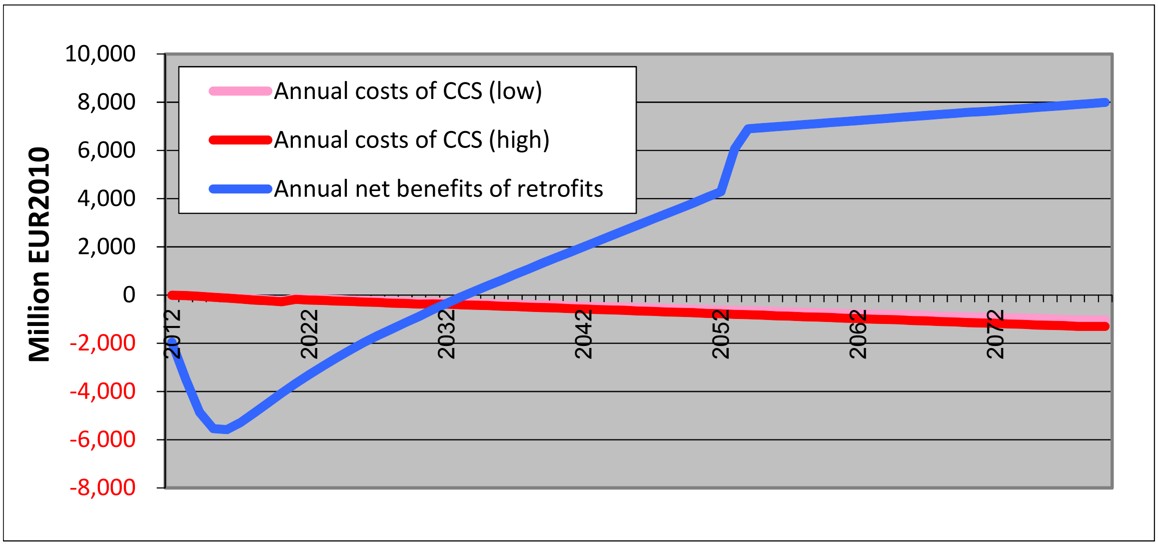

Figure 1-17: Annual costs of capturing through CCS the same amount of CO_2 as the *S-DEEP2* scenario (low- and high-bound estimates) vs. annual net benefits of retrofits in *S-DEEP2*.

In addition to the private energy saving benefits, social external benefits such as the positive impacts of avoided emissions need to be accounted for too. These refer to the increased welfare effects of reduced climate change and of avoided impacts on human health and on ecosystems caused by non-GHG pollutants (NO_x, SO_x, PM and NMVOC). They have been estimated as the avoided external cost of CO_2 and non-GHG pollutants, which were retrieved from IPCC's 4th Assessment Report and the EU's *NewExt* project. As shown in **Table 1-7** and **Figure 1-18**, social (external) benefits are larger than energy saving benefits in the short, middle and long-term. A proper comparison of costs and benefits in the social cost-benefit analysis framework incorporating additional external benefits (e.g., reduced energy poverty-related excess winter mortality) would likely yield more attractive cost-benefit ratios.

Cumulative external benefit of avoided GHG and non-GHG emissions mitigation (undiscounted, Billion Euros 2010)		**2025**	**2050**	**2080**
S-DEEP1	External benefit of avoided carbon emissions	2	22	137
	External benefit of avoided non-GHG emissions	9	74	189
	Total external benefits (undiscounted)	**10**	**96**	**326**
S-DEEP2	External benefit of avoided carbon emissions	2	37	174
	External benefit of avoided non-GHG emissions	14	122	325
	Total external benefits (undiscounted)	**16**	**158**	**499**
S-DEEP3	External benefit of avoided carbon emissions	3	47	186
	External benefit of avoided non-GHG emissions	19	160	355
	Total external benefits (undiscounted)	**23**	**207**	**541**
S-SUB	External benefit of avoided carbon emissions	2	23	90
	External benefit of avoided non-GHG emissions	9	73	177
	Total external benefits (undiscounted)	**11**	**96**	**267**

Table 1-7: External benefits of avoided CO_2 and non-GHG emissions

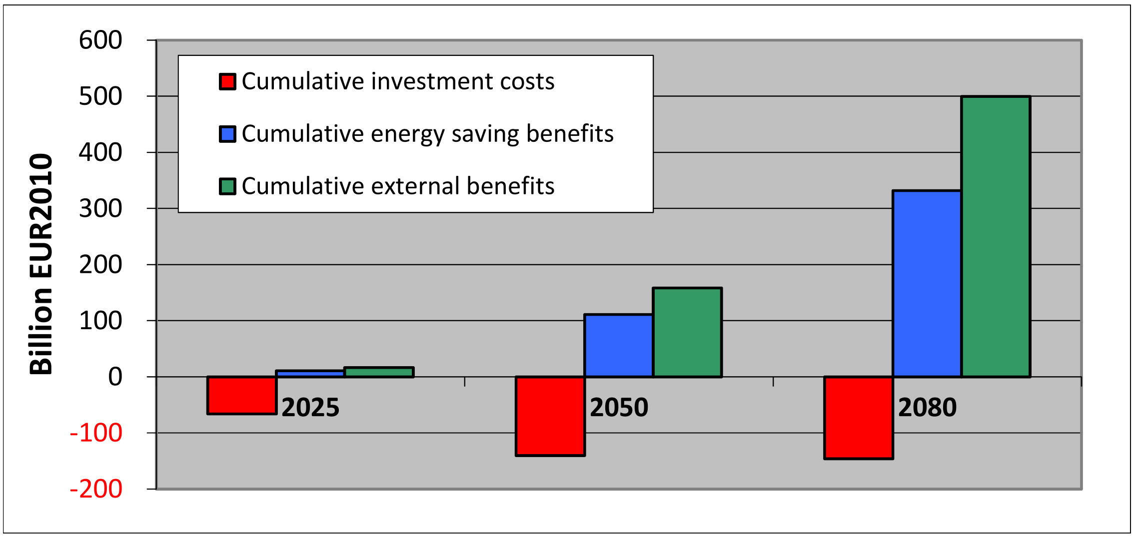

Figure 1-18: Cumulative investment costs vs. cumulative private energy saving benefits and social external benefits – undiscounted (*S-DEEP2* scenario).

1.4.2 Employment impacts

Direct impacts on the construction sector. All the scenarios will engender remarkable net employment benefits in virtually all sectors of the economy, but in particular in the construction sector. Direct impacts in construction, divided by skill level, can be seen in **Table 1-8** and **Figure 1-19** for 2020.

The evolution of direct impacts throughout the programme is shown in **Figure 1-20**, which clearly displays the initial ramp-up period of deep and suboptimal scenarios, followed by a gradual decrease in total direct employment caused by the learning factor (less workers are needed to complete the same amount of work as experience accumulates and economies of scale develop). This reduction in is an element to be considered when analysing the durability of the additional jobs created in the construction industry by the renovation programme[C3].

	S-BASE	S-DEEP1	S-DEEP2	S-DEEP3	S-SUB
Million Euros invested in 2020	1,104	2,999	4,997	6,995	2,154
Employment - in thousand FTE					
Professional	1	7	11	16	3
Skilled	12	34	57	80	26
Unskilled	6	5	8	11	5
Direct labour involved: total	19	46	76	106	34

Table 1-8: Direct labour impacts on the construction sector, divided by skill level

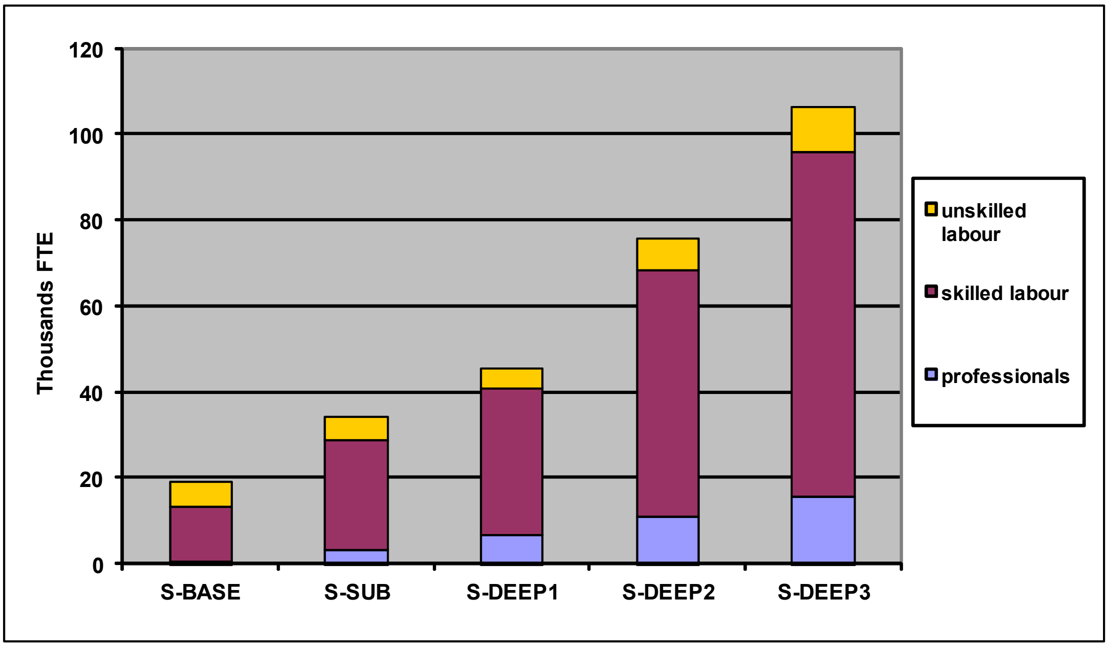

Figure 1-19: Direct employment impacts in construction by skill level in 2020

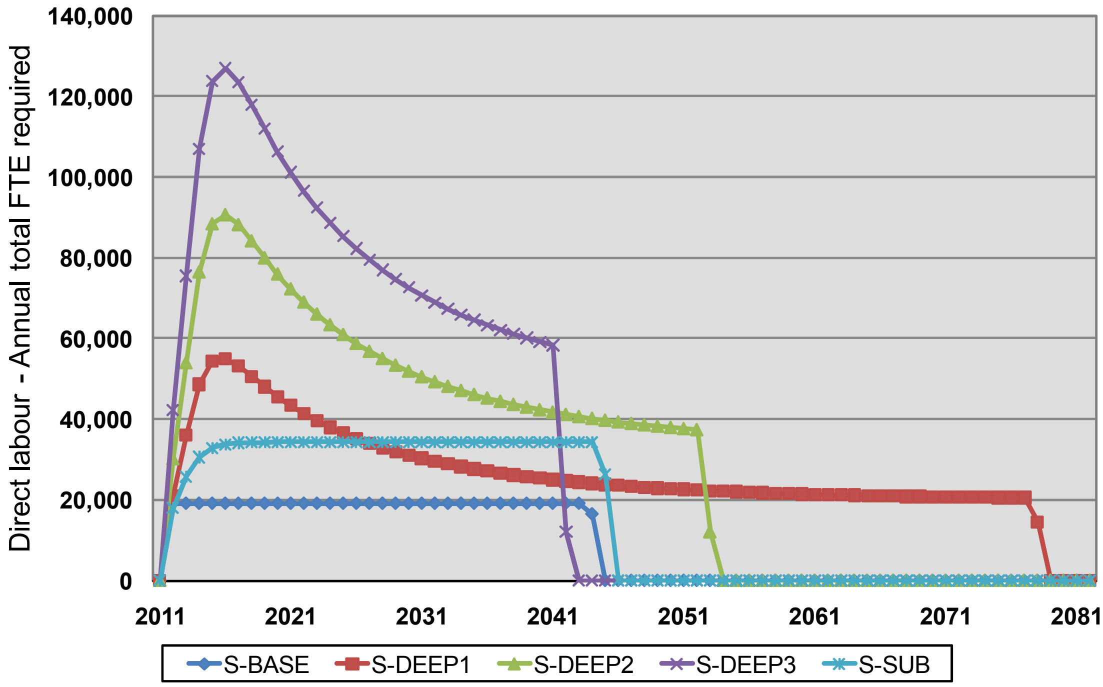

Figure 1-20: Evolution of direct employment impacts on the construction sector

<u>Total net employment impacts.</u> **Table 1-9** summarizes the direct, indirect and induced employment impacts in Poland in 2020 for all scenarios. The table disaggregates between the three types of induced impacts listed in **Section 1.1**: those generated by the additional jobs created by the investment in construction, those destroyed by job losses in the energy sector, and the induced impacts fuelled by the energy cost savings. The results of the total (direct, indirect and induced) impacts are also displayed graphically in Błąd! Nie można odnaleźć źródła odsyłacza..

	S-BASE	*S-DEEP1*	*S-DEEP2*	*S-DEEP3*	*S-SUB*
Million Euros invested in 2020	1,104	2,999	4,997	6,995	2,154
In thousand FTE units					
Direct impacts on construction sector	19	46	76	106	34
Direct impacts on energy supply sector	-4	-5	-9	-12	-6
Indirect impacts from investments in construction	22	59	99	139	43
Induced impacts from additional jobs created by investments in construction	16	42	70	98	30
Indirect impacts from reduced demand for energy	-9	-12	-19	-27	-13
Induced impacts from lost jobs created by reduced demand for energy	-7	-9	-15	-21	-10
Induced impacts from energy savings	3	5	7	10	5
Total net employment impacts in 2020	40	126	210	294	83

Table 1-9: Total impacts for the renovation scenarios in 2020, by type of impact

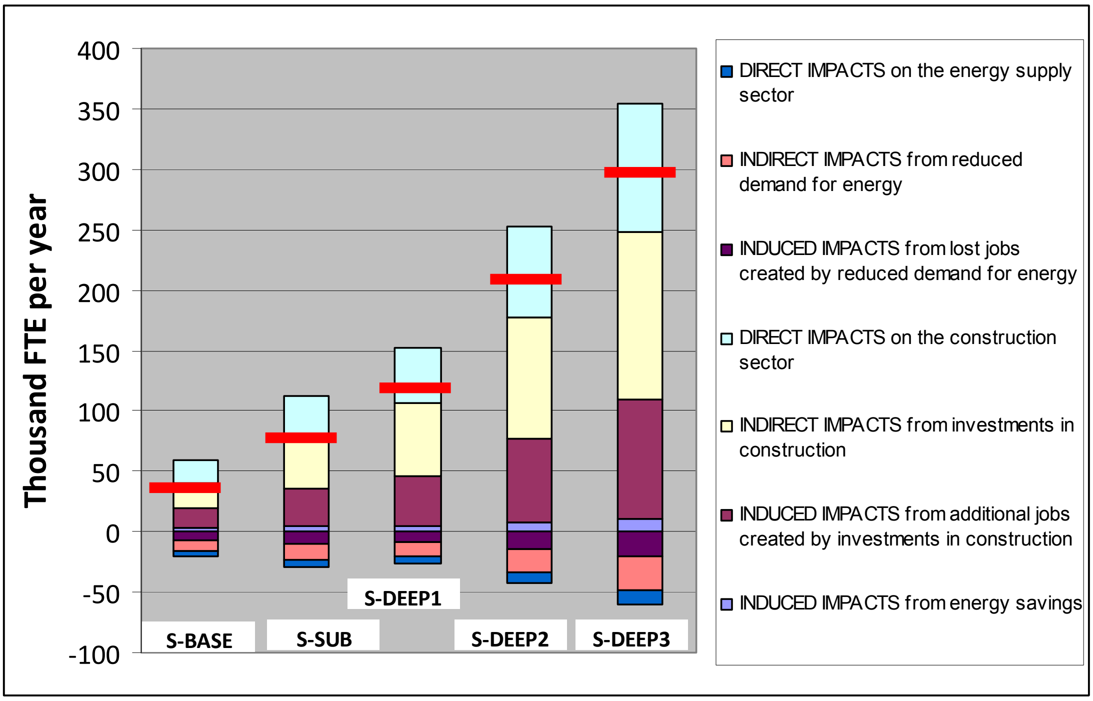

Figure 1-21: Total impacts for the renovation scenarios in 2020, by type of impact. The size of the net impact is marked with the red crossing line.

These results indicates that hundreds of thousands of net additional jobs can be created in 2020 by deep renovation scenarios, ranging from the 86 thousand additional FTE per year of *S-DEEP3* scenario to the 254 thousand additional jobs created by the more intensive S-DEEP1 scenario. Note that additional jobs are calculated by subtracting the 40 thosuand jobs estimated for *S-BASE* scenario (i.e., the ones currently generated by the Thermo-modernization programme) to the ones estimated for the proposed intervention scenarios (*S-SUB* and *S-DEEP*). These findings suggest that building renovations are employment intensive interventions, with a potential to create many additional jobs if implemented at large scale.

The employment results of *S-DEEP* scenarios for 2020 were normalised to FTE per million Euros of investment and then compared with other selected results from the literature (see **Annex A**) and those obtained in the Hungarian study (Ürge-Vorsatz et al., 2010). As shown in **Figure 1-22**, the results obtained in *S-DEEP* scenarios both in Hungary and Poland are above the averages reported by previous studies in Western Europe and the USA. This divergence, which is significant but not excessive may be at least partially explained by the fact that in economies in transition (such as Poland and Hungary) the labour intensity of the economy is typically higher than in other regions as the relative price of labour is lower than the price of capital and technology.

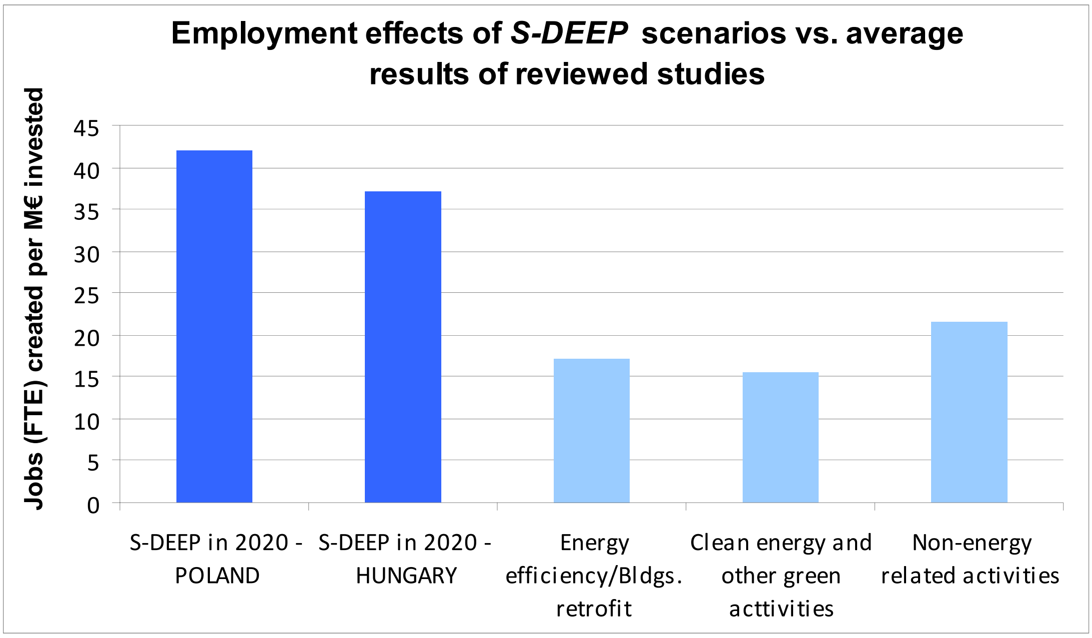

Figure 1-22: Comparison of employment effects of S-DEEP scenarios in Hungary and Poland with other climate, energy and non-energy related interventions

The model contained in this research also allowed estimating the total employment impacts in the short and medium term, as can be seen from **Figure 1-23**. As with direct impacts, the initial increase is due to the ramp-up period (both in *S-SUB* and *S-DEEP* scenarios). The substantial mid-term decline in the net amount of jobs forecasted by the model is due to the direct, indirect and induced negative employment effects related to the energy savings (for all scenarios) and also to the expected reduction in per unit renovation costs (only in *S-DEEP* scenarios).

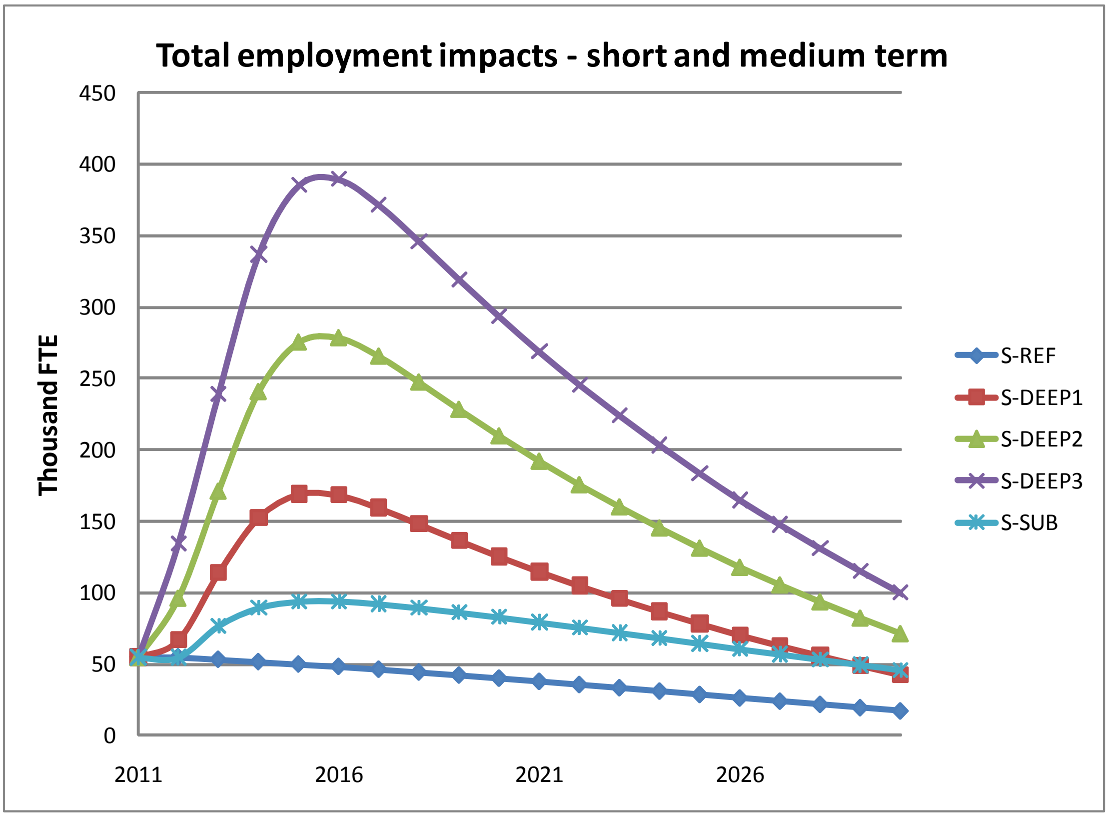

Figure 1-23: Short- and medium-term view of the net employment impacts in the different scenarios

<u>Effects on other economic sectors.</u> **Table 1-10** and **Figure 1-24** show the indirect and induced impacts in 2020 of the retrofit scenarios in all sectors of the Polish economy. They indicate that many of the positive employment impacts are due to the indirect and induced impacts of renovation activities (i.e., in the sectors supplying materials and other inputs to the construction sector, plus in all other sectors of the Polish economy positively impacted by the programmes): in 2020, 75% to 80% (depending on the scenarios) of the gross positive employment created corresponds to these categories, whereas 20% to 25% of those jobs are created in the construction sector. By major economic sectors, the largest indirect and induced employment gains can be seen in the following industries: community and social services (a very labour-intensive sector), manufacturing (a sector making an important contribution to the program through the supply materials for the renovations) and the construction sector itself (the demand of the construction industry increase because of the retrofits, e.g., new dwellings for the new employees, more facilities for the construction industries implementing the retrofits, etc.).

On the side of the negative effects, most job losses occur as indirect and induced effects (in 2020, around 80% of the gross negative employment effects are foreseen in these categories in all scenarios). It is worth noting that not very significant job losses (up to a maximum of 6% of the gross job losses in 2020, depending on scenarios) occur in the mining and quarrying sector (compare figures in **Table 1-9** and **Table 1-10**). This is a particularly sensitive sector for Poland in terms of its employment losses, as proven by the resistance of organised labour unions to mine closures during the transition period.

In thousands FTE units	S-BASE	S-DEEP1	S-DEEP2	S-DEEP3	S-SUB
Agriculture, hunting, forestry and fishing	1.3	4.0	6.6	9.3	2.7
Mining and quarrying	-1.2	-0.7	-1.0	-1.5	-1.5
Manufacturing	6.6	20.1	33.5	46.9	13.6
Electricity, gas and water supply	-3.7	-4.0	-6.5	-9.1	-5.2
Construction	11.6	32.2	53.7	75.2	22.9
Wholesale and retail trade, restaurants and hotels	1.5	4.5	7.6	10.6	3.0
Transport, storage and communications	0.8	2.8	4.7	6.5	1.8
Finance, insurance, real estate and business services	1.2	4.3	7.2	10.1	2.7
Community, social and personal services	7.3	23.5	39.3	55.0	15.5

Table 1-10: Indirect and induced impacts for the renovation scenarios in 2020, by macro-sectors

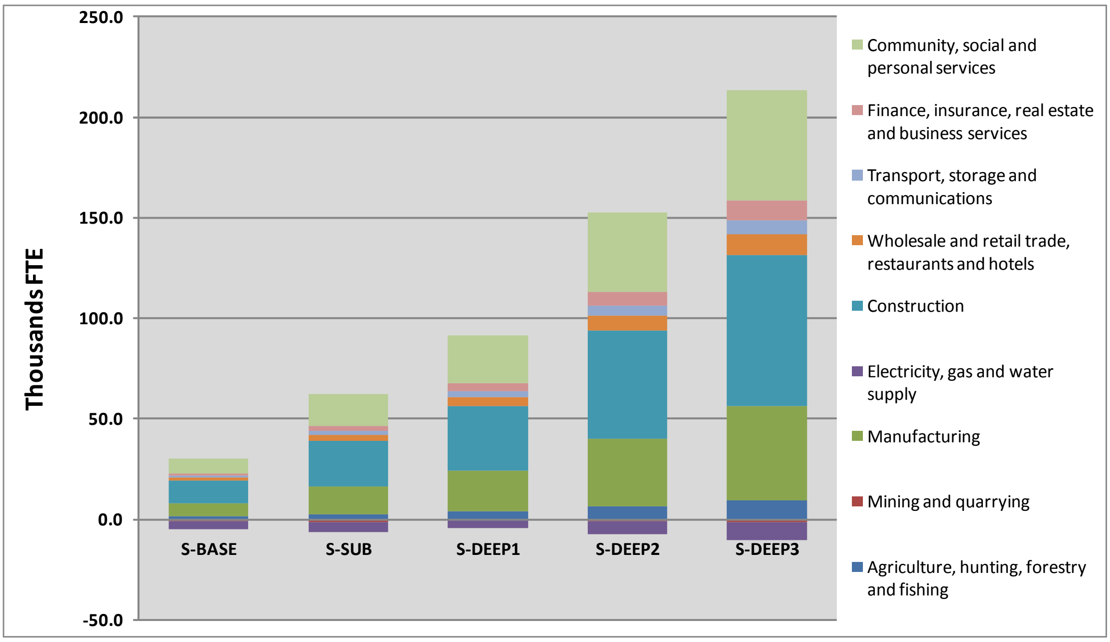

Figure 1-24: Indirect and induced employment effects of the increase in demand in construction, by macro-sector

1.5 Qualitative discussion on selected aspects

1.5.1 Geographical and temporal distribution of employment effects

Geographic distribution of employment effects. Since buildings to be renovated are as geographically disperse as the population, direct employment effects will be likely distributed evenly across regions, typically through local small- and medium-size enterprises (SMEs) implementing the retrofits. As for the indirect effects, there may be some concentration in those regions where factories of construction materials (e.g., double- or triple-glazed windows, high-quality doors, insulation materials, etc.) are located. Besides, since construction materials are also imported, especially in advanced retrofits, this may lead to a transfer of indirect employment effects (perhaps not properly captured by I/O analysis) beyond the borders of the country (see **Section 7.3.1**). Finally, it is expected that induced effects are the most widely distributed employment impacts because the additional income coming from the additional wages in the construction sector plus the energy savings will be spent by households living all over the country on a wide range of goods and services produced in many different regions.

Temporal durability of employment effects. The model predicts a gradual but steady decline in total net employment figures, with all scenarios (including the baseline) producing negative results from around the year 2040 (see **Section 7.3.3**). However, it must be noted that the induced positive employment effects of the energy savings are likely to be underestimated by the model, whereas the negative induced employment effects of the reduced demand for energy may be overestimated (see **Section 8.1.2**). In any case, it can be argued that the length of the programme (several decades) ensures the long-term character of the employment effect and the over 30 years needed for completing the programme under different scenarios are not far from the active lifetime of a construction worker.

1.5.2 Effects on the labour market

Potential bottlenecks: supply of labour, materials and skill level implications. The results show that deep renovations will require a large amount of additional workers at its peak – in the range of the 254 to 86 thousand FTE per year (87,000 to 27,000 in the construction sector alone).. Partially because of this reason, the model used in this research assumed a ramp-up period during which the construction industry adapts to the new demand and responds to a possible shortage of supply in workers or skill. However, a question might arise if there is a sufficient supply, in the required locations and skill level, of workers in Poland to satisfy this demand.

The demand for workers will be spread across all skill levels: from construction entrepreneurs, to college-trained professionals, skilled and unskilled workers. While the supply of entrepreneurs and professionals is perhaps easier, issues may arise for the supply of skilled and unskilled workers. In theory, unskilled workers can be supplied by the unemployed and inactive Polish labour force; in practice, the skills of the unemployed and inactive may differ from those needed in the programme, and these workers may have high reservation wages (i.e., a high minimal wage for which they would be willing to work). Besides, it is also expected that the implementation of the programme would attract foreign workers, probably more for the unskilled jobs segment.

Special attention should be paid to the sectors manufacturing the construction materials and equipment needed for deep renovations. As in the case of skilled labour, the demand for such intermediate inputs would grow substantially as a result of the programme. If the supply does not react at the required pace (i.e., new producers entering the market, existing companies starting new production lines, etc.), materials would become another bottleneck that may increase the costs of deep renovation.

Effects on costs of wage changes and workers' productivity. Wages will respond to the increase in demand for workers, and they will increase as firms compete for the scarce skills. This may increase the costs of retrofit projects and slow down the rate of renovations and the output of upstream industries. In addition, such a general wage increase can have adverse *spillover* effects on the whole labour market, as the labour costs may increase in other industries competing for the same labour force. On the other hand, the model forecasts that the costs of renovation will decrease and the productivity of workers grow as a consequence of economies of scale and the learning factor. All in all, these phenomena may suggest that a more gradual renovation programme has a less negative impact on the supply of labour from these perspectives.

Age and gender composition of the labour force. The progressive ageing of the Polish population, which affects the composition of the whole Polish labour market, must be taken into account in the long-term. It can be forecasted that thanks to the improvements in health conditions and life expectancy, more people over 60 will be economically active in the coming years, though this is not likely to make a big difference in the construction sector, where most of the work needs physical strength.

From a gender perspective, it can be noted that that most of the new employees in the construction sector will be men, at least in the unskilled and skilled workers-level (new position at the architect/engineering level are more likely to be filled by women as well as men). On the other hand, the programme will also have large indirect and induced impact on other sectors such as *Community, social and personal services* where the proportion of female employment is higher, thus helping to balance the gender composition of the employment created.

The informal labour market. About 9.5% of the Polish employees – namely the younger and those with low educational achievement – work in the *grey zone* of the labour market. The construction sector is certainly not immune from this phenomenon, and it is in fact likely to be one of the most affected industries. Though a more in-depth analysis would be required, it can be hypothesised that the initial scarcity of qualified labour might give more contracting power to the employees, forcing the employers to declare all the wages or register the workers for social security. Otherwise the programme may actually offer an opportunity to reduce grey labour in the construction sector because if the State finances the renovations, it may also want to ensure that taxation and social security rules are respected by workers and enterprises.

1.5.3 Effects on other sectors

The energy sector and the rebound effect. It is suspected that the results of the I/O analysis overestimate the job losses in the energy and related sectors (mining and quarrying). There are two main reasons for that. First, the energy sector is characterised by its large fixed costs (i.e., a fixed amount of labour and capital is required to keep systems running independently of the amount of energy delivered). Then, I/O methodology calculates employment effects assuming a linear relationship – defined by a labour intensity expressed in FTE per thousand PLN – between the output and the amount of employees of each sector. Thus a large reduction in energy demand, such as the one expected in *S-DEEP* scenarios, may result in a less than proportional (i.e., smaller than estimated in the model) reduction of the workforce. Second, the energy that is not needed in the domestic market might also be exported, if regional and world markets are ready to accept the increased supply of Polish fuels (particularly coal).

Furthermore, negative impacts in the energy sector might be attenuated by the so-called *rebound effect*, which forecasts an increase in the previously reduced energy demand caused by the reduction of the per-unit price of energy services and the increased disposable income available to consumers generated by energy-efficiency measures.

1.5.4 Additional co-benefits of energy efficiency in buildings in Poland

Fiscal effects, social security spending and enhanced economic activity. Energy efficiency investments are also expected to have positive fiscal impacts in the form of reduced government expenditures (e.g., unemployment benefits, social welfare payments and energy costs of public buildings) and enhanced government revenues (additional tax collection), though a certain decrease in revenues associated with lower energy consumption also has to be accounted for. Though evidence is still scarce, a recent study of the fiscal effects of energy efficiency investments in Germany has found out that for each euro invested public authorities get back 4 to 5 euros in the form of additional contributions and taxes paid by firms and employees and reduced public expenditure on unemployment and social benefits. In Hungary, an *ex ante* assessment of a hypothetical state-funded residential energy efficiency investment programme has estimated that the additional State revenues (VAT, personal income tax and social security contributions) derived from the additional investment and consumption more than compensates the expenses incurred by the State (subsidies and reduced VAT collection from energy savings).

In addition, increase in employment rates triggered by retrofits will help buffer the pressure on Poland's public pension funds, which are likely to increase in the mid-term because of demographic changes. In a context of constrained government budgets and an ageing population, increasing employment rates in Poland stands out as one of the few long-term strategies for ensuring the sustainability of public pension systems.

Finally, a large-scale retrofit programme will create a broad range of new business opportunities along the supply chain of retrofits, many of them involving local entrepreneurs and located in rural areas. Being a first mover in supplying large-scale deep retrofits may also help developing industries potentially become future exporters of retrofit materials and technologies to the Central and Eastern European region and beyond. This would further enhance Poland's production and employment levels and contribute to reduce its trade balance deficit.

Improved air quality. Poland has one of the most coal-dependent economies in the world. In the building sector nearly 45% of the energy consumed in buildings for space and water heating is directly provided by this cheap and very polluting fossil fuel, either through direct use or through district heating plants. Since coal's emission intensities of non-GHG pollutants (i.e., NO_x, SO_x, PM and NMVOC) are up to several hundred times bigger than those of cleaner fuels, Poland is currently the largest SO_x emitter and the second largest emitter of PM_{10} and $PM_{2.5}$ of the EU. When compared to those aggregated figures, the model's results indicate that current heat consumption in buildings is responsible for 43% of Poland's total annual SO_x emissions and 62% of PM_{10} emissions.

Though the use of coal makes Poland a less energy dependent country, it also results in significant impacts on the human health and the environment. The coal-related emissions of harmful pollutants cause, among others, the acidification and eutrophication of ecosystems, plant damage, respiratory and cardiovascular health problems and reduced lung function. Additionally, the benzo(a)pyrene (BaP) – a compound specifically related to coal and biomass combustion – causes cancer in humans and is known to be a problem in areas where domestic coal and wood burning is common like Western Poland, the Czech Republic and Austria. These emissions result in substantial costs to the society in the form of direct welfare loss (i.e., pollution-related morbidity and premature mortality) and additional health care system and social security costs (i.e., hospitalization and treatment, sick leaves and working days lost, etc.). A recent study by the European Environment Agency (EEA) on air pollution has found Poland is the EU Member State with the second largest human health and ecosystems damage (5 to 13 billion Euros per year) from industrial facilities – including power plants – after Germany.

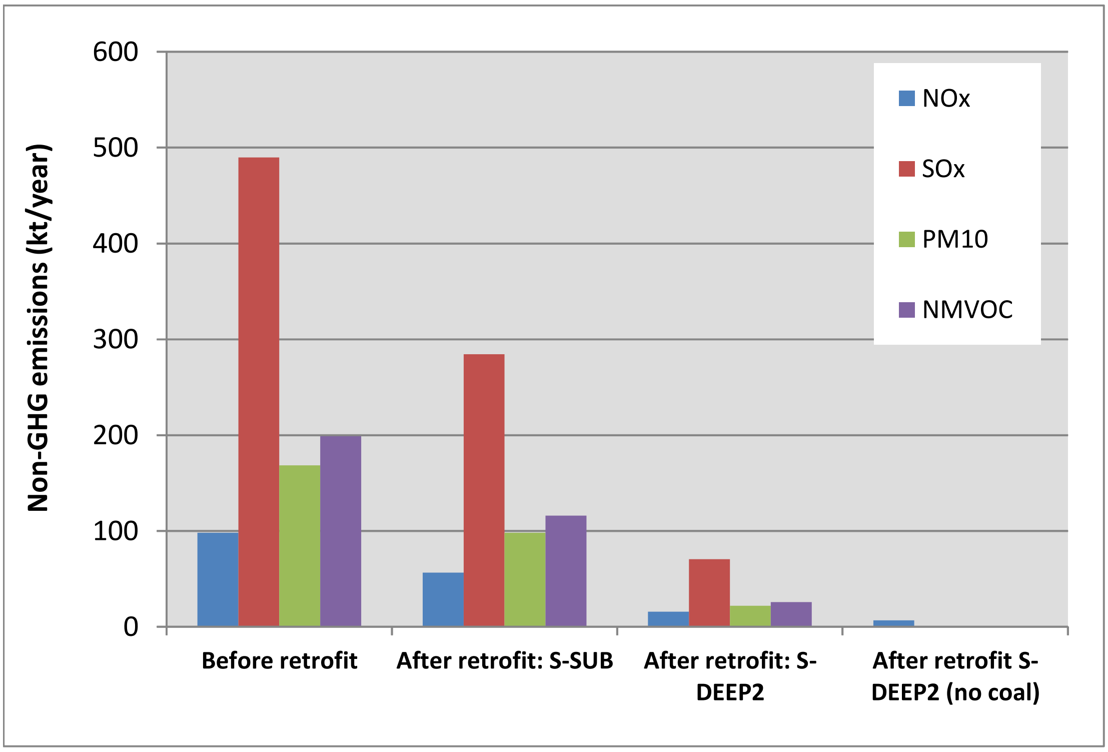

Figure 1-25: Estimated total non-GHG emissions (1000 t per year) of the building sector before and after the retrofit of all buildings (by scenarios)[2]

Deep retrofitting the Polish building stock has substantial positive effects on human health and the ecosystems because it reduces 84% of the estimated 2010 total non-GHG emissions associated with energy use in the building sector. If retrofits are complemented by a *phase-out* of coal (i.e., assumed to be substituted by natural gas), this would lead to nearly zero non-GHG emission levels once all buildings are retrofitted (see **Figure 1-25**). This means

[2] *S-DEEP2* scenario is shown as representative of S-DEEP scenarios.

avoiding 43% and 62% of Poland's total (i.e., building and non-building related) current SO_x and PM_{10} emissions once all buildings are retrofitted.

Energy poverty alleviation. According to Eurostat, 22% of the Polish population (8.6 million people) stated that they were unable to afford to keep their home adequately warm during the cold season as an average for 2005-2010. In the same period, nearly 17% the population (6.4 million people) stated to be in arrears on utility bills. These figures are well above the EU27 average and indicate that a large fraction of Poland's households struggle to cover their domestic energy needs, which results in dwellings heated to substandard levels, a higher incidence mental and physical diseases, energy poverty-related excess winter mortality and financial imbalances for utility companies. Like air pollution, energy poverty also increases health care system and social security costs: in the UK, a study has estimated that the excess cold hazard costs of energy inefficient homes (F- and G-rated) to the National Health System (NHS) amounts to € 225 million (£192 million) per year.

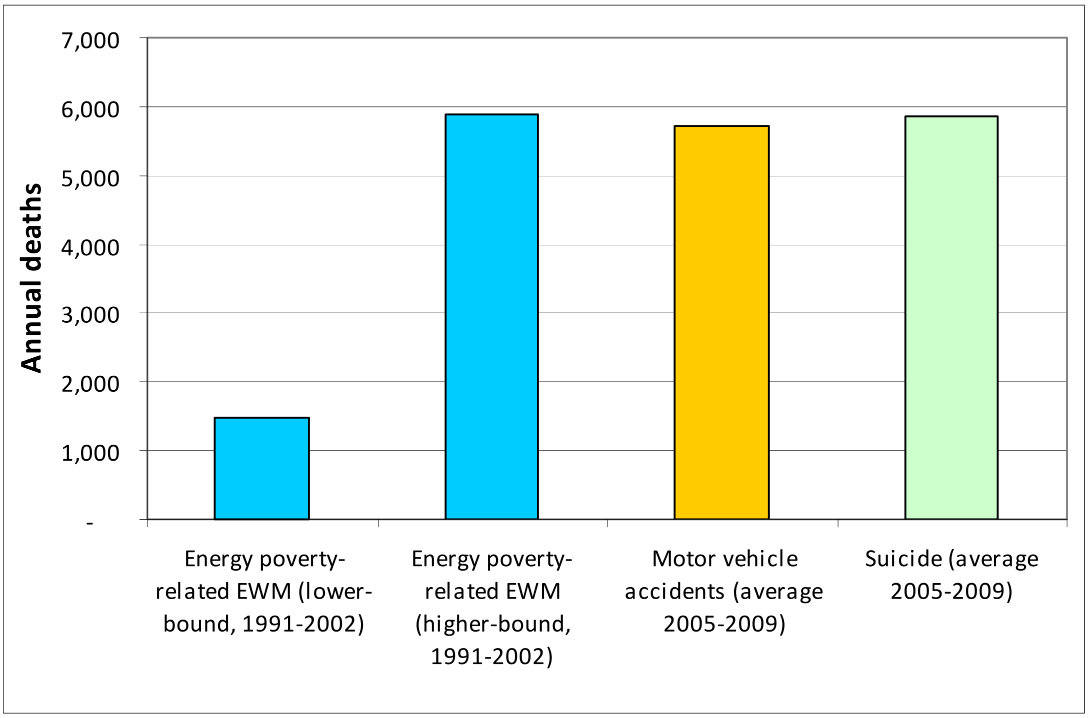

Figure 1-26: Comparison of energy poverty-related excess winter mortality (EWM) and mortality caused by motor vehicle accidents and sucides[3].

Some initial calculations made for this report indicate that up to nearly 6,000 excess winter deaths – an amount comparable to the annual number deaths from road traffic accidents or suicide – can be avoided yearly by ensuring sufficient indoor thermal comfort levels of Polish dwellings. In that sense, deep retrofitting Poland's residential buildings may eventually eradicate energy poverty and its related excess winter mortality, whereas suboptimal retrofits will take only partial steps towards alleviating this problem.

[3] The reported lower-bound and higher-bound estimates correspond to the 10%-40% range of excess winter deaths that can be attributed to fuel poverty according to the literature.

Increased rental and resale price of properties. Compared to similar units, retrofitted buildings have a number of advantages that make them more attractive to buyers of the housing rental and sale markets, thus increasing their market prices. To illustrate, a hedonic price analysis of the Dutch housing sector – an early adopter of the EU EPBD energy labeling system– recently found out that A-labelled homes (similar to the ones that result of the implementation of deep retrofits) obtained a 12.1% price premium in transaction prices as compared to similar G-labeled homes. On the contrary, F-labeled properties only received a 1.7% premium as compared to G-labelled homes.

That the price of the dwelling as an asset increases as a result of the intervention is important because it provides an additional financial incentive for households to participate in the programme and for maintaining the energy efficiency gains achieved with the retrofits: households will not only be saving money while living there but can also sell or rent their property at a better price.

Energy security. Even though natural gas only supplies 8.2% of the heat consumed by the building stock, a large fraction of it (69%) is imported. Deep renovation programmes thus allow Poland to significantly reduce natural gas imports and thereby improve energy security: by 2030, the reduction in natural gas imports delivered by the most ambitious deep renovation scenario *S-DEEP3* will be considerably higher (77% of the average imports of the 2006-2009 period) than those achieved by the baseline scenario (21%). Though the expected exploitation of domestic shale gas reserves will help to further reduce gas imports, efficiency in buildings is likely to be the cheapest and cleanest way to reduce imports even in light of this possible alternative.

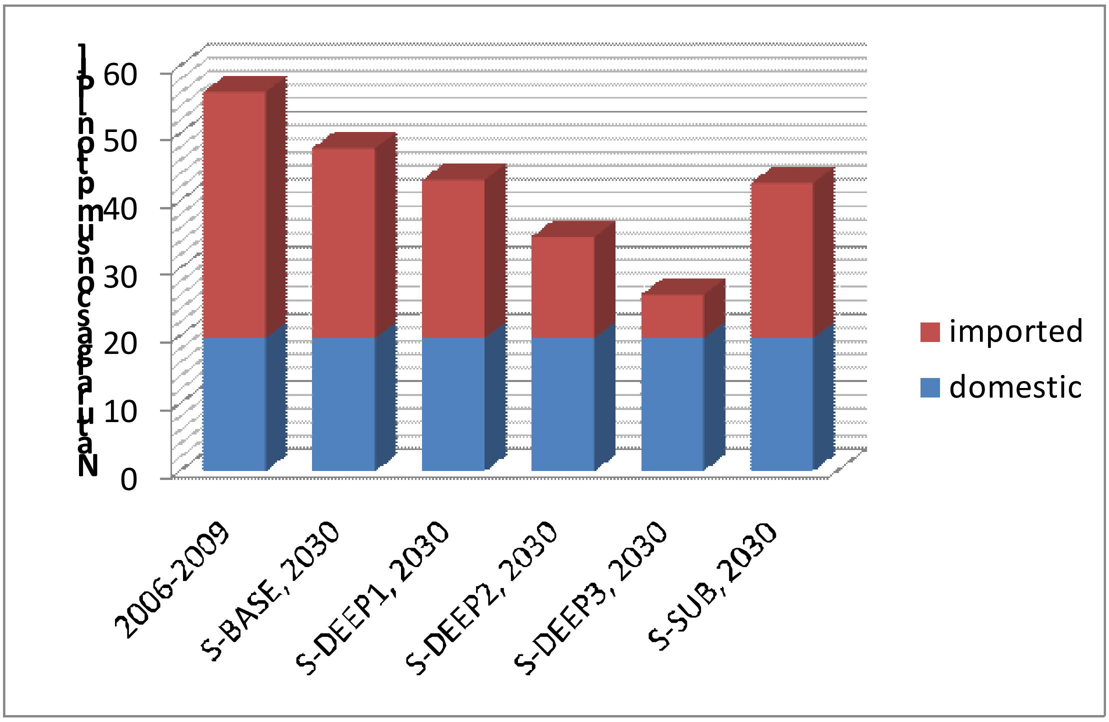

Figure 1-27: Natural gas saved in the year 2030 by retrofit scenarios

1.5.5 Financing

While this study has not defined in any detail a financing scheme and avoided dealing with these aspects, it is an issue that any serious attempt to apply the programme must take into consideration. As the vast majority of Polish households may not dispose of sufficient up-front capital to invest in a deep retrofit of their house, a financing formula has to be devised in order to make such a programme viable. In this regard, it is believed that a *pay-as-you-save* scheme (i.e., the upfront costs of the refurbishment are financed by a third party, which lends the money, an obligation to repay is linked to the property over an extended number of years and the repayments are calculated to be less than the energy savings obtained) would be a feasible option for the proposed intervention in Poland.

To the extent that the State supports its implementation, the building renovation programme will exert additional pressure on an already constrained government budget. This could be avoided by using the funds currently spent on the Thermo-modernization programme, by increasing the increasing the allocation of EU funds to energy efficiency programmes for buildings (an increase from the current less than 1% to 5% would release some 500 million Euros per year) and by making use of the existing subsidies to the otherwise declining coal-mining sector (these subsidies have amounted to an average of 440 million EUR per year in the period 1990-2006). This source of capital can be complemented with revenues from the mandatory EU ETS allowance auctions from 2013. Additional financing tools identified are pay-as-you-save schemes (PAYS), energy company obligations and sale of CO_2 quota.

1.6 Conclusions and recommendations

The study has demonstrated that up to 84% of the Polish buildings energy use for space and water heating, and its corresponding CO_2 emissions, can be avoided by a consistent and wide-spread deep retrofit programme in the country. At the same time, it has also highlighted the important risk related to less ambitious renovation programs. If the existing Thermo-modernization programmes (i.e., reducing around 30% of the present per dwelling energy use on average) is further implemented, this will result in a significant *lock-in* effect (52% of the 2010 energy consumption and CO_2 emissions). On the other hand, if a sub-optimal upgrade of the building renovation programme (*S-SUB* scenario, delivering a 50% reduction in energy use per dwelling) takes place, it will save only 42% of the current energy use, locking in another 42% of the 2011 building heating-related emissions at the end of the programme. The implementation of less than deep retrofits means that reaching ambitious mid-term climate targets, such as the IPCC's 50-85% reduction range needed by 2050, will become more difficult and expensive to achieve.

The realisation of a suboptimal rather than a deep renovation scenario also results in other compromises, too, such as in terms of energy security enhancements. By 2030, the continuation of the *business-as-usual* retrofits of the Thermo-modernization programme (*S-BASE* scenario) would reduce buildings-related natural imports by 21% instead of the 77% that can be achieved with the most ambitious deep renovation scenario (*S-DEEP3*).

With regard to the employment effects, the results of the study clearly indicate that adopting a high efficiency retrofitting target close to passive standard house would result in substantially higher employment benefits, than the *business-as-usual* (Thermo-modernization programme, *S-BASE* scenario) and sub-optimal renovation (*S-SUB* scenario) alternatives. In particular, the study has demonstrated that a large-scale, deep renovation programme in Poland can create over 250 thousand net additional jobs per year by 2020, as opposed to 40 thousand in the suboptimal scenario. These figures include the workforce losses derived from the permanent energy savings achieved (direct employment losses in the energy supply sector and other supply-chain related sectors) and discount the amount of *business-as-usual jobs* (40 thousand FTE per year) that the baseline scenario is currently providing. Many of the positive employment impacts are due to the indirect and induced impacts of renovation activities (i.e., in the sectors supplying materials and other inputs to the construction sector, plus in all other sectors of the Polish economy positively impacted by the programmes): in 2020, 75% to 80% (depending on the scenarios) of the gross positive employment created corresponds to these categories. By skill levels, most of the direct jobs created in the construction sector are in the skilled (manual) workers category in both *S-SUB* and *S-SDEEP* scenarios. Finally, it is argued that the length of the programme ensures that the employments created are long-term, though a substantial reduction in the number of net jobs created by the programme is expected as a result of the energy savings and the learning factor. And the fact that the whole building stock is considered for renovation implies that the new jobs are likely to be distributed throughout the country as renovations are usually carried out by local small and medium enterprises.

The analysis of the financial costs and benefits of the proposed intervention has concluded that in the long-term, the energy saving benefits accrued through retrofits surpass investment costs, and that deep retrofits are preferable to suboptimal from an undiscounted private costs vs. benefits perspective. by 2080, the total accumulated undiscounted net benefits of *S-DEEP3* amount to 203 billion Euros, whereas *S-DEEP2* and *S-DEEP1* generate 186 and 122 billion Euros each. Among deep scenarios, a more ambitious retrofit rate delivers more undiscounted net benefits and is a preferable alternative as long as potential negative effects (e.g., destruction of the previously created employment because of the learning factor, bottlenecks in the supply of labour, capital and materials) are dealt with. Because of the existing trade-offs, *S-DEEP2* scenario can be suggested as a rate of retrofit that maximizes net benefits without compromising the feasibility of the programme or creating imbalances in the labour and other markets affected by the retrofits.

However, when compared to alternative mitigation strategies, building retrofits are a more cost-effective solution. If the amount of carbon emissions avoided by the retrofits until 2080 were to be mitigated in power plants through CCS (carbon capture and storage, a relevant alternative mitigation option according to Poland's energy strategy), this would be achieved at a higher cost and without many of the co-benefits provided by retrofits.

Additionally, since Polish building rely to a large extent on coal for their space and water heating energy demand, substantial improvements in the air quality of urban areas (reductions of $NO_{x,}$ SO_x, PM and NMVOC atmospheric concentrations) are also expected, with further decreases in these emissions coal is substituted by cleaner fuels as a soruce of heat in buildings. Thus a first estimate of the social (external) benefits of the CO_2 and non-GHG emissions avoided by the retrofits has concluded that these are larger than the private energy saving benefits.

Energy efficiency investments are also expected to have positive fiscal impacts in the form of reduced government expenditures (e.g., unemployment benefits, social welfare payments and energy costs of public buildings) and enhanced government revenues (additional tax collection), though a certain decrease in revenues associated with lower energy consumption also has to be accounted for. They also increase social security contributions, helping to ensure the sustainability of public pension systems and create a broad range of new business opportunities along the supply chain of retrofits that have the potential to reduce Poland's trade balance deficit.

Deep retrofits provide a long-term solution to energy poverty too. This a significant problem in Poland, where a significant fraction of the population are unable to afford to keep their home adequately and in arrears on utility bills. Some initial calculations indicate that up to nearly 6,000 excess winter deaths – an amount comparable to the annual number deaths from road traffic accidents or suicide – can be avoided yearly by ensuring sufficient indoor thermal comfort levels of Polish dwellings. They also enhance the rental and resale prices of retrofitted properties in real estate markets. This co-benefit, which is reaped privately by the owners of the property, is key to ensure the adoption of the measure by households for maintaining in the long-term the energy efficiency gains achieved with the retrofits.

The research has also found that redirecting the current subsidies to carbon-intensive sectors (such as coal mining) and making a wiser use of available EU funds would make available nearly 1 billion euros per year, an amount that by itself would cover between 25% to 50% of the full annual costs of renovating Polish buildings at a rate of 195,000 units per year (*S-DEEP1* scenario). This source of capital can be complemented with revenues from the mandatory EU ETS allowance auctions from 2013. Additional financing tools and sources identified are pay-as-you-save schemes (PAYS), energy company obligations and sale of CO_2 quota.

To create the conditions for a smooth implementation of the programme, the public administration should be decisively involved in the planning and the financing of the retrofit programme, to promote initiatives that would reduce the risks of supply bottlenecks (such as labour, material or finance supply) and in making sure that the renovations deliver the expected energy savings, so as to ensure the financial practicability of the intervention.

To sum up, decision-makers of today's Poland have the possibility to unlock the potential for creating additional jobs while greatly reducing the energy costs of households and public buildings, largely improving the air quality of the country's urban areas, reducing to some extent the its natural gas dependency and making further contributions to mitigate climate change. Between the three options presented, the results indicate that deep (i.e., passive house-type) renovations are recommended as compared to suboptimal and *business-as-usual* retrofits. High efficiency renovations create more jobs, save more energy, reduce more GHG and non-GHG emissions, decrease to a larger extent the energy dependency of the nation and over time eradicate energy poverty.

2 Background and rationale

2.1 Poland's energy and climate challenges

Poland, unlike other Member States which are far from complying with their emission targets set under the EU's burden sharing agreement (e.g., Spain, Ireland or Portugal), will have little problem to meet its Kyoto Protocol commitments[4]: the required 6% reduction of its base year emissions by 2012 is largely surpassed by the 33.2% reduction already recorded in 2009. This is a common feature of most CEE Member States, which are all (but Slovenia) below their Kyoto Protocol GHG emissions targets (EEA, 2011a). Even the mid-term target set by the EU's Climate and Energy Package (20% to 30% reduction by the end of the present decade) can be likely achieved by this group of countries with a bit more than *business-as-usual* policy action.

However, it is believed that Poland is approaching a decisive stage for the future of its energy system. The energy intensity of its economy is still significantly higher than the EU27 average: as shown by Eurostat data, Poland uses more than twice the energy a typical Member State needs to produce one unit of output (GDP). There is also an urgent need to upgrade Poland's energy system, primarily its electricity and district heating infrastructure; half of which is more than 30 years old and reaching the end of its lifespan. Substantial capital investments are required for the whole energy system. This includes developing new sources of energy (such as shale and other forms of unconventional gas, if their potential is confirmed) along with the infrastructure for carbon capture and storage – to accommodate the continued use of coal for electricity and heat production. However, in the long-term the country's traditional reliance on coal is unsustainable, due to environmental factors and because national production is already failing to meet domestic demand. In 2008, for the first time, Poland became a net importer of coal, and hard coal production is expected to decrease sharply by 2030 – 2015 for lignite (IEA, 2011).

In addition, the country is facing major challenges from the European economic crisis, despite its better performance compared to other Member States. This means struggling businesses, increasing unemployment and tightening budgets for social welfare spending and energy-related projects and subsidies.

In this context, buildings are key to both a robust, secure and socially attractive energy infrastructure upgrade. They also provide an alternative path to stronger economic growth. A more robust and cost-effective upgrade of Poland's energy infrastructure offers an avenue for alternative capital investments. This renewal can deliver large demand-side energy cost savings as opposed to an unsustainable and costly expansion and retrofit of the supply-side capacity. And it gives the opportunity to tackle simultaneously a number of important challenges linked to the energy consumption in buildings identified at a national level.

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4 Poland's annual aggregated GHG emissions have stabilized at around 395.000 Gg CO2eq (30% of its base year 1988 emissions: 563,443 Gg CO2eq) – data compiled in accordance with Intergovernmental Panel Climate Change (IPCC) methodology and submitted to UNFCCC; they exclude emission and absorption from the sector "land use, land use change and forestry" (National Centre for Emissions Management, 2010)

First, even though Poland is not pressed in the short and middle term to comply with emissions reduction targets, ambitious long-term mitigation goals to be met by the middle of the century in order to avoid the worst effects of climate change are likely to require much more decisive policy action. In its last assessment report, the IPCC (2007) has estimated that a reduction of 50% to 85% of global carbon emissions (as compared to the year 2000 level) will be necessary by 2050 to limit the increase in global mean temperatures above the 2.0-2.4 °C level. Assuming that this large reduction will be borne to a large extent by OECD nations (such as Poland) and that the currently in place policy frameworks are insufficient to comply with those long-term carbon emission targets, it is clear that substantial further emission reduction efforts are needed. In the case of Poland as well as for other CEE Member States, the current low level of carbon emission is mostly the result of the decline of the inherited energy-inefficient heavy industry and overall restructuring of the economy in the 1990s (with the exception of the road transport sector, whose emissions have increased steadily). Once the restructuring of the economy was finished, Poland's total carbon emissions are stabilized at around 390 Tg per year since 2000 (EEA, 2011a). Thus, unlike the reduction achieved spontaneously through the transition period, halving (or even reducing further) its year 2000 emission level by 2050 will require the active application of a range of ambitious policies aimed at a large decarbonisation of the Polish economy.

Second, the economic and political changes occurred after 1989, which amplified income inequality and poverty, resulted in substantial increases in previously subsidized prices of utility services with fuel poverty (i.e., the inability to afford enough energy services for satisfying the household's basic needs, particularly heating) arising as a new energy challenge with clear social implications. Though this is quite an insufficiently researched topic in Central and Eastern Europe, an initial exploration of the extent and characteristics of the phenomenon in Poland indicates that as an average for the period 2005-2010, 22% of the Polish population (8.6 million people) declared to be unable to afford to keep their home adequately warm in the cold season (14.8% for 2009, the last year with available information) and that 16.8% of the population (6.4 million people) declared to be in arrears on utility bills (12.5% in 2009). These figures are well above the 2005-2010 average for the EU27 for both indicators (Eurostat, 2011a). Besides, an initial expenditure-based estimate of Poland's fuel poverty rate has indicated that over 40% of households must allocate more than 10% of their income to maintain a sufficient heating comfort (Kurowski, 2011). According to this study, the social groups that most affected by fuel poverty in Poland as measured by the energy expenditures vs. income relationship include:

- According to their income source: pensioners, farmers and low skilled workers.
- According to the size of the settlement: people from villages and towns between 20,000 to 100,000 inhabitants.
- Users of small dwellings (40-54 m^2).
- Small size households (1 and 2-person households).

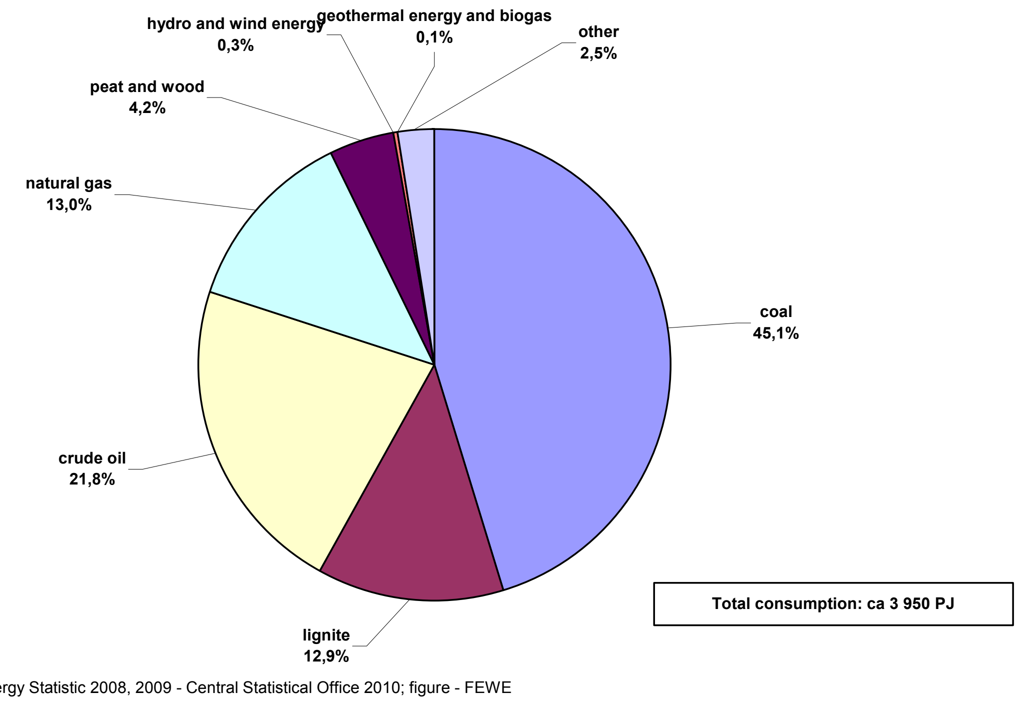

Figure 2-1: Primary energy consumption in Poland in 2009

Source: FEWE, based on data from Energy Statistics 2008, 2009; Central Statistical Office, 2010.

Third, Poland's energy demand is largely met by coal, unlike in many other CEE nations where coal has been largely substituted by the natural gas, a cleaner (and mostly imported) fuel. As shown in

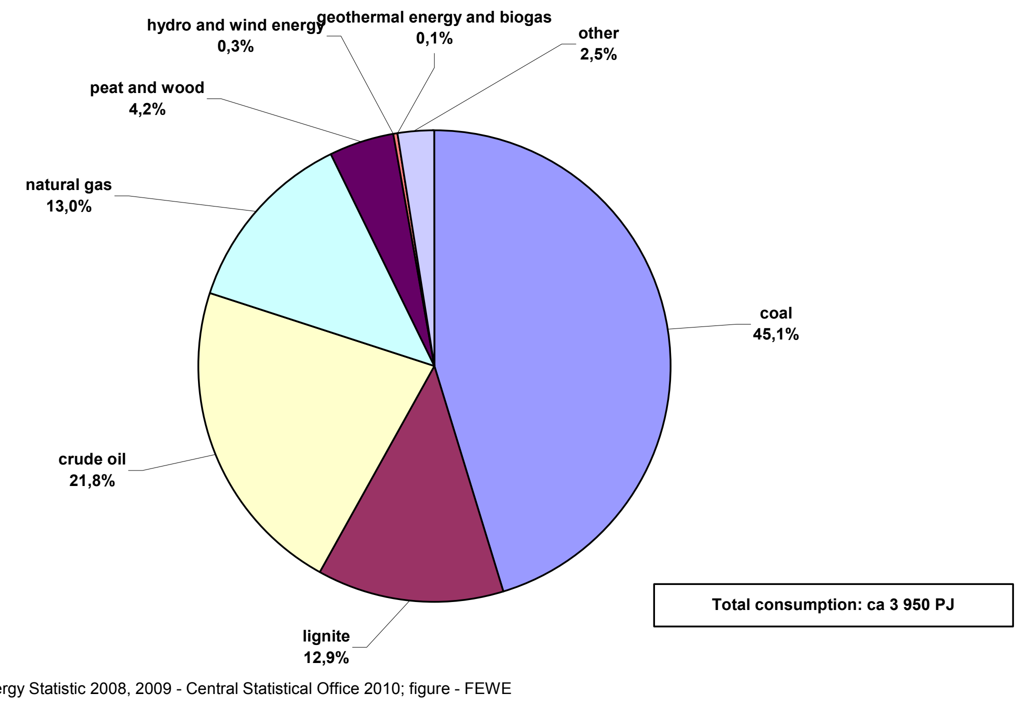

Figure 2-1, the primary energy consumption in Poland in 2009 (3,950 GJ or 14,220 TWh), is comprised mostly of coal (45%), lignite (13%), crude oil (22%) and natural gas (13%). The coal and lignite are mainly extracted domestically. This makes Poland one of the few

remaining coal-based economies of the world. The reasons for this are the country's large endowment of coal and also historical: during the period of the socialist State (1945-1989), Poland had limited access to foreign currencies to buy imported fuels such as oil or gas. Coal mining was thus supported through subsidies and coal prices were regulated to ensure its affordability (Suwala, 2010). This has resulted in a less energy dependent energy system (from imported natural gas) but also in higher emission levels of non-GHG pollutants – namely nitrogen oxides (NO_x), sulphates (SO_x), particulate matter (PM) and non-methane organic volatile compounds (NMVOC) – with demonstrated negative effects on human health and the ecosystems (see **Section 8.4.2**). Additionally, continuing subsidies to the coal mining sector are a burden to the government budget and detract scarce financial resources that could be used for the provision of cleaner energy services (see **Section 8.5**).

Fourth, though perhaps less of a concern than in other CEE nations, improving the energy security is also a priority for the Polish government since most of the crude oil is imported and 69% of the natural gas consumed in Poland is imported (the remaining 31% of natural gas comes from indigenous production of nitrified natural gas) (Energy Statistics, 2008; 2009; Central Statistical Office, 2010). Thus, the Polish government is planning to actions to prevent future difficulties with the supply of natural gas and crude oil. More concretely, according to the action plan of Poland's Energy Policy until 2030 (Resolution no. 202/2009 of the Council of Ministers of 10 November 2009), there are plans to: i) build a LNG plant for receiving liquefied natural gas (LNG); ii) finalize contracts for a wide range of natural gas sources, both inside and outside Europe; iii) establish a sustainable management policy for domestic gas resources to allow an extension of the natural gas reserve base in the territory of Poland; iv) invest for extending the natural gas extraction in the territory of Poland; v) diversify supplies by building a transmission system for natural gas supplies from the north, west, and south, as well as by making connections to primarily meet the requirement of supply sources diversification. It can be argued that some of these actions involve developing large supply-expansion infrastructures that require large amounts of money (that could be invested in demand-side solutions) without bringing many of the energy saving and non-energy benefits of the efficiency-enhancing solutions.

2.2 The energy performance of Polish buildings

2.2.1 Context: the energy intensity of the Polish economy

Currently, Poland's energy intensity is slightly lower than the average of the EU 10 new Member States but still higher than the EU27 average and the average for Western European Member States (see **Figure 2-2**).

For the forthcoming future, the document *Poland's Energy Policy until 2030* forecasts a progressive decrease of the energy and electricity intensity of Poland until almost half of the current (2010) levels by the year 2030 (see **Figure 2-3**). These figures suggest that Poland has a large potential to reduce its energy consumption through improvements in the energy efficiency of the various end-use sectors.

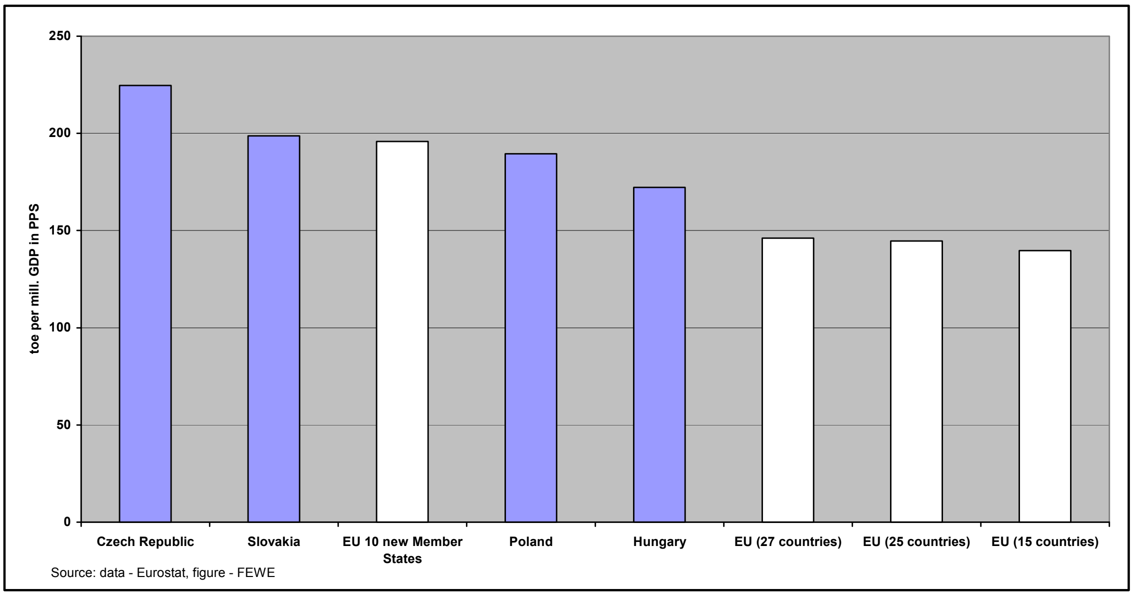

Figure 2-2: Energy intensity of EU-27, EU-25, EU-15 (pre-2004 Members), EU-10 new Member States and selected CEE countries (2007)

Source: Eurostat

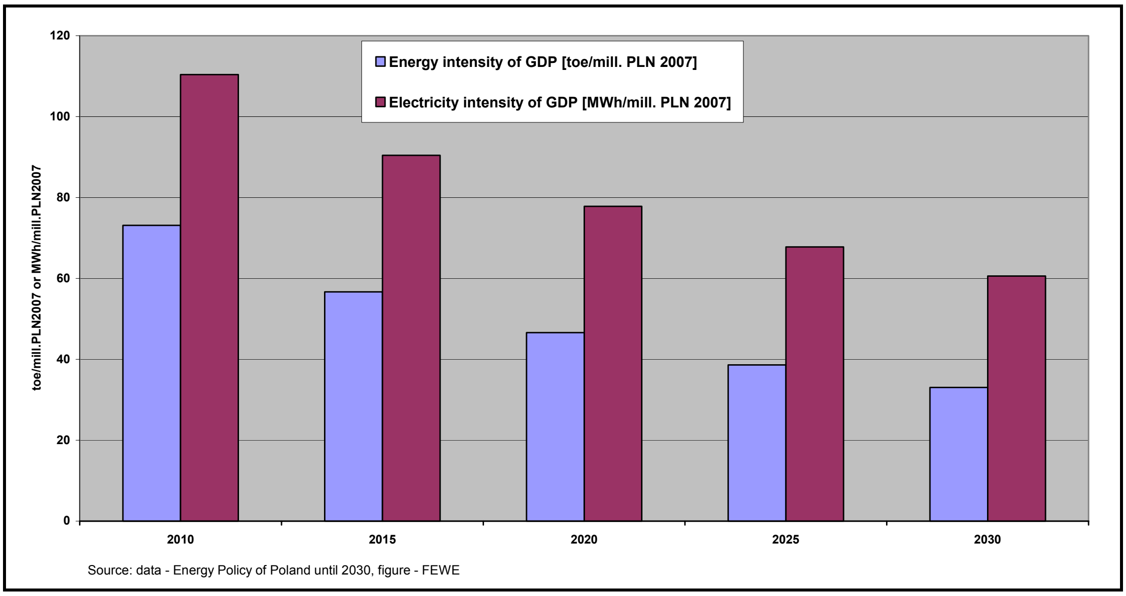

Figure 2-3: Energy and electricity intensity of Poland GDP till 2030

Source: Energy Policy of Poland until 2030 (Polish Ministry of Economy 2010).

2.2.2 Indicators on the energy performance of buildings in Poland

In Poland, buildings are key to the climate and energy challenge as they are responsible for over 25% of its final energy consumption (in 2009, 783.5 PJ) and constitute the second most demanding end-use sector of the country after industry (see **Figure 2-4**). One of the reasons why this figure is so high is the inefficiency of its building stock. Poland ranks among the top-ten EU27 countries in terms of specific energy consumption for space heating scaled to EU average climate (142 kWh/m^2/year for the period 2005-2008, as presented in **Figure 2-5**).

Among the 10 new EU Member States, only Latvia, and Hungary have less energy-efficient residential buildings according to this metric. (Neither data for public buildings nor for energy consumption for water heating in Poland were available in the Odyssee database).

The high energy consumption of the average residential unit in the region is believed to be a consequence of the long time subsidised energy prices and of the deterioration of the residential stock. Although multi-family apartments – in principle less energy demanding because of their better living space vs. exposed wall area ratio – are a common feature in CEE urban settlements, this effect is believed to have been "many times offset by the lack of basic energy efficiency requirements in apartments" (Ürge-Vorsatz et al., 2006, p. 2285).

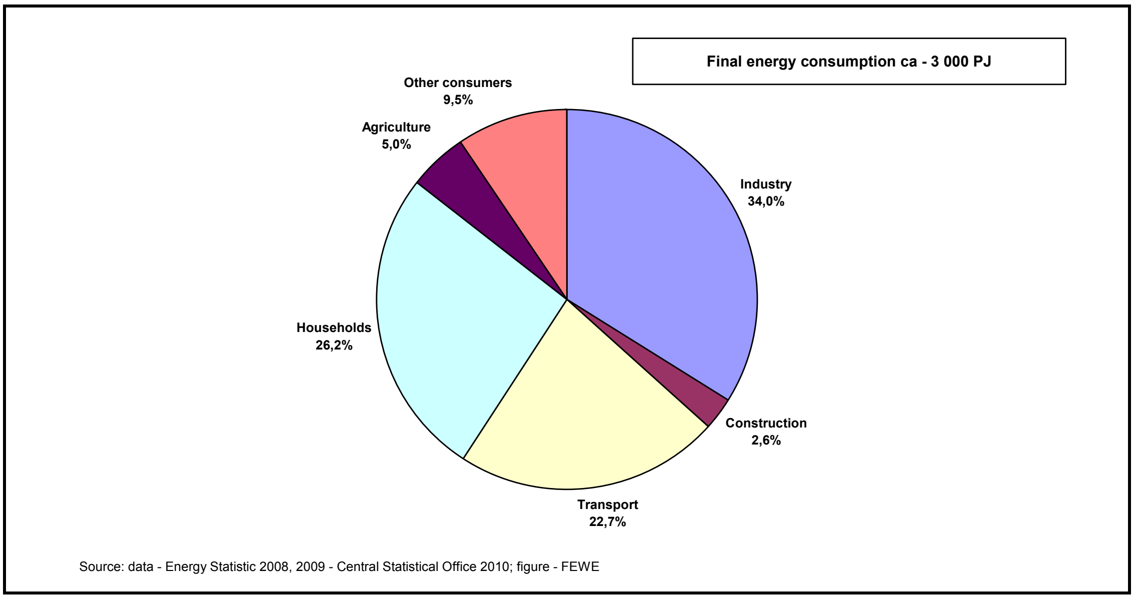

Figure 2-4: Final energy consumption in Poland in 2009

Source: FEWE, based on data from Energy Statistic 2008, 2009; Central Statistical Office, 2010

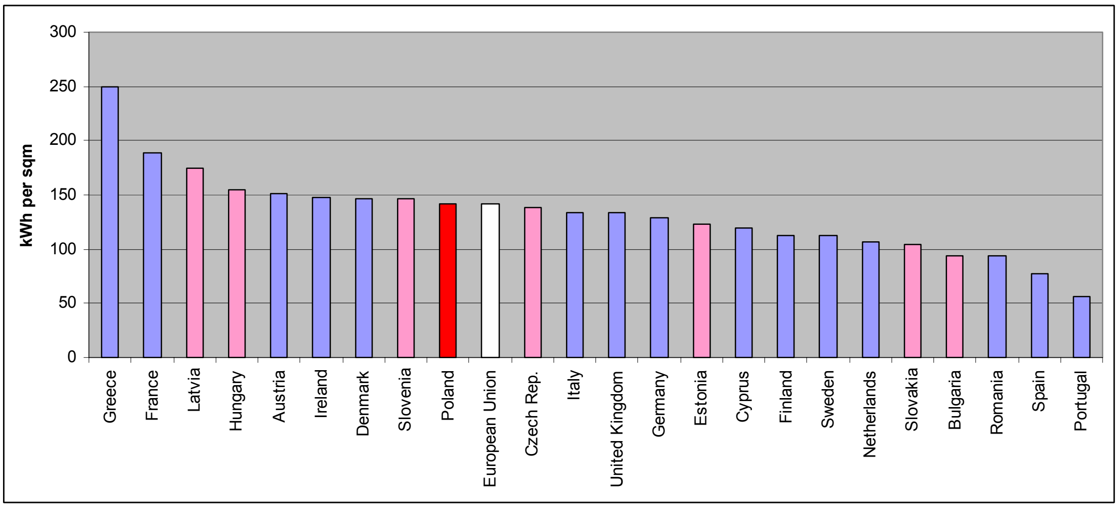

Figure 2-5: Energy consumption of households per m^2 for space heating in 2005-2008, scaled to the EU average climate

Source: Odyssee database

Interestingly, Poland was one of the best performers among the EU Member States according to the ODEX energy efficiency index[5] of households for space heating. As presented in **Figure 2-6**, Poland was the Member State with the best record in the first half of the 2000s decade, although later on it was surpassed by other countries such as Romania, Slovenia , Netherlands and Germany. This indicator measures the improvements achieved in this particular end-use sector independently of the absolute performance (e.g., kWh/m^2/year) at the start (thus all the country series start at a normalized 100 units level).

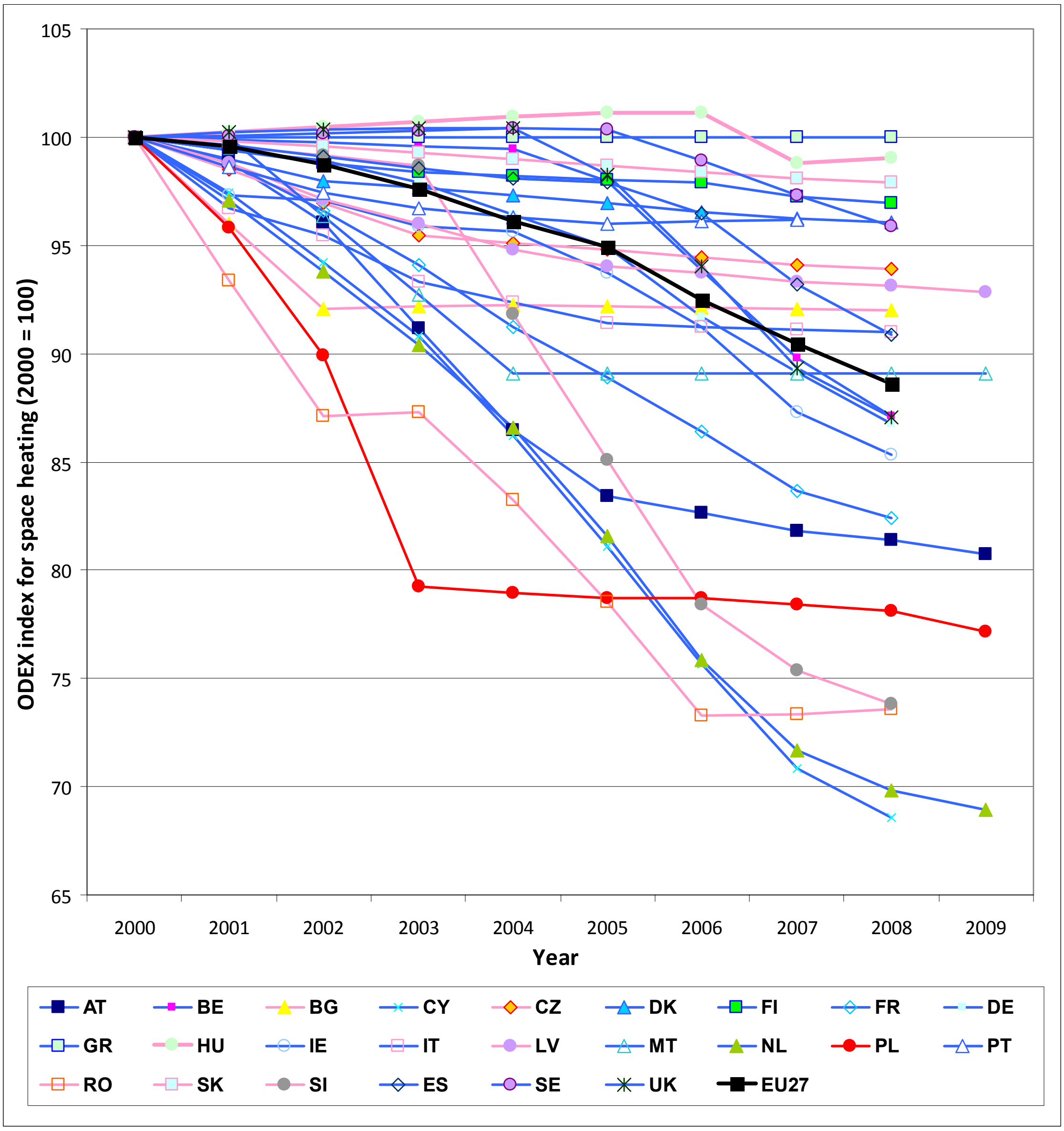

Figure 2-6: Evolution of the ODEX energy efficiency index for households. Poland vs. EU27 Member States, 2000-2007 [2000 = 100].

[5] ODEX is a top-down index to measure energy efficiency progress by country, by sector and by all final consumers. It can be retrieved from ODYSSEE [URL: http://www.odyssee-indicators.org/], database of energy efficiency indicators in Europe run by ADEME. The index is calculated upon unit consumption using different physical units (e.g., toe m^{-2}; kWh per appliance; liters per 100 km, etc.). For the household sector ODEX index, 8 end-uses/equipment are accounted for (Lapillone et al., 2004): heating, water heating, cooking and five large appliances (refrigerators, freezers, washing machine, dishwashers and TV).

It can be argued that this improvement is result of the effective implementation of energy efficiency policies by the State and by regional and local governments in Poland (see next **Section 2.2.3**). This improvement allowed offsetting to some extent the increase in residential floor area registered in Poland between 1996 and 2008. In 1996, the number of dwellings was 11,5 millions and their average specific energy consumption was 407 kWh/m^2; in 2008 the number of dwellings was above 13 millions and their average specific energy consumption was 234 kWh/m^2. It means that despite increase final energy consumption by households above 24% to 215, 75 TWh in 2008 final energy intensity decreased above 42% in this period because increased floor area of dwellings 32%[6].

2.2.3 Current policy elements and the way forward

Putting in place the right policy tools and institutional contexts contributes to unlock the energy saving potential of the residential stock of CEE countries. This seems to have been the case of Poland in the last 10 to 15 years, as shown in the previous **Section 2.2.3**, where a number of instruments have improved to some extent the energy performance of its building stock.

Probably the most important policy element of the Polish building energy efficiency policy framework is the Thermo-modernisation Act (Act of 18th December 1998, with later amendments) and Fund, which since 1999 have been providing technical and financial assistance to energy end-users in residential buildings. Projects usually supported by the programme include end-use improvements in residential buildings, reduction of energy losses in heat distribution networks and the substitution of conventional energy sources by non-conventional sources, including renewable energies (EnerCEE.net, 2011). Presently, some 2,2% to 3% of all Polish dwellings go through thermal retrofitting, thus benefiting from the programme. In addition, all newly constructed buildings and dwellings (some 0.8% to 1.3% of the entire residential stock) are obliged to meet the technical requirements.

The Thermo-modernization Fund is administrated by the by the State-owned *Bank Gospodarstwa Krajowego* (BKG), which offers, among others, thermomodernization bonuses. Theses bonuses are a form of state support for the investor who carries out the thermomodernization project and consists of 25% rebate in the loan used for the project (i.e., therefore the investor only pays off 75% of the amount of the loan). The thermomodernization bonus only partakes to investors who benefit from a loan granted by banks co-operating with BGK and it cannot be used by enterprises that carry out thermomodernization enterprise with their own funds. Clients can be councils, housing co-operatives, commercial law partnerships, housing associations and natural persons such as detached family house owners. It is financed from the EU via the Ministry of Infrastructures, in charge of its administration, and more specifically from sources like the Operational Program Infrastructure and Environment and the Green Investment Scheme" (GIS) that

[6] Source: Calculation by FEWE based on Local Database of Central Statistical Office (Number of dwellings and their floor area), Energy Statistics 1996, 1997; Central Statistical Office, 1998 and Energy Statistics 2008, 2009; Central Statistical Office, 2010 and Energy Efficiency 1998 – 2008; Central Statistical Office, 2010.

benefits from the revenues of emission trading fees. Retrofits of the public buildings are also supported by these financial sources.

The Thermo-modernization programme does not support deep retrofits and its available financial means are limited. Besides, the relatively costly procedures and transaction costs are an obstacle for single family houses owners to apply.

In addition to this, a number of initiatives run in parallel at the regional (*voivodeship*) level. That is the case of EU-funded Regional Operational Programmes administrated by respective Managing Institutions located at Marshall Offices and coordinated by the Ministry of Regional Development. An example of such initiatives is the programme operated by the the Śląskie Voivodeship, which includes an activity 5.3 on clean Air and RES aimed at local governments and their associations aimed at, among other goals, the thermo-modermisation. Other progammes are implemented by *voivodeship* Environmental Protection Funds. For example, the Dolnośląskie *voivodeship* supports through special loans the thermo-modernization investments including insulation, windows and doors replacement. Another example is the Silesian *voivodeship* Fund for Environmental Protection, the first in Poland to manage a credit line for co-financing new boilers and solar collectors and energy saving buildings (Bank Gospodarstwa Krajowego, 2011; National Fund for Environmental Protection and Water Management, 2011; Program Regionalny – Narodowa Strategia Spojnosci, 2011).

The information available indicates that this range of initiatives existing at the national and regional level is not achieving very substantial savings as compared to state-of-the-art technologies such as the passive house concept (applicable both to new buildings and retrofits). That way, as presented in **Section 5**, the average energy savings achieved by the retrofits supported by the Thermo-modernisation programmes are in the region of the 30% of the building's previous energy use. There is thus a risk that if shallow retrofits keep on being implemented at the existing rates and intensities, a large fraction of the energy and emissions saving potential of the Polish building stock will be *locked-in* (see **Sections 6.1** and **6.3**).

2.3 The situation of the labour market in Poland

A very relevant feature of the Polish labour market as compared to other EU Member States is its low employment and activity rates (i.e., the proportion of people in working age – 15-64 years – who are employed).

More in general, the situation in Poland as of 2011 can be described with two key indicators obtained from Eurostat:

- Its average unemployment rate (i.e., percentage of the active population without a job) for the last two years (2009 and 2010) is at the 8.9% level, a percentage that is in line with the EU27 but is also well above the best performers of the EU (**see** Błąd! Nie można odnaleźć źródła odsyłacza.).

- Its employment rate in the last two years (2009 and 2010) has averaged 59,3% of the working age population, a proportion well below the EU27 average – see Błąd! Nie można odnaleźć źródła odsyłacza.. Among CEE Member States, Poland had the fourth lowest employment rate of this group of countries after Slovenia, Czech Republic and Romania.

A number of negative effects of low employment rates – namely increased poverty rates, erosion of knowledge and skills of the labour force, deteriorating health and life expectancy, poor socialisation, risks to the long-term sustainability of the social security systems, etc. – have been identified for the Hungary (Cseres-Gergely et al., 2009) and are equally relevant for the Polish case.

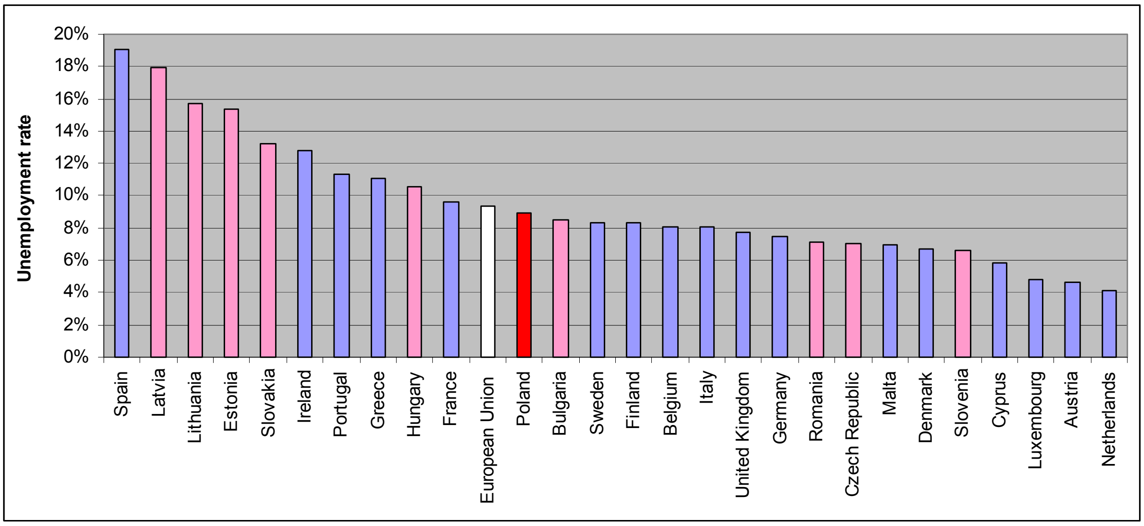

Figure 2-7: Evolution of the ODEX energy efficiency index for households. Poland vs. EU27 Member States, 2000-2007 [2000 = 100].

Source: Odyssee database

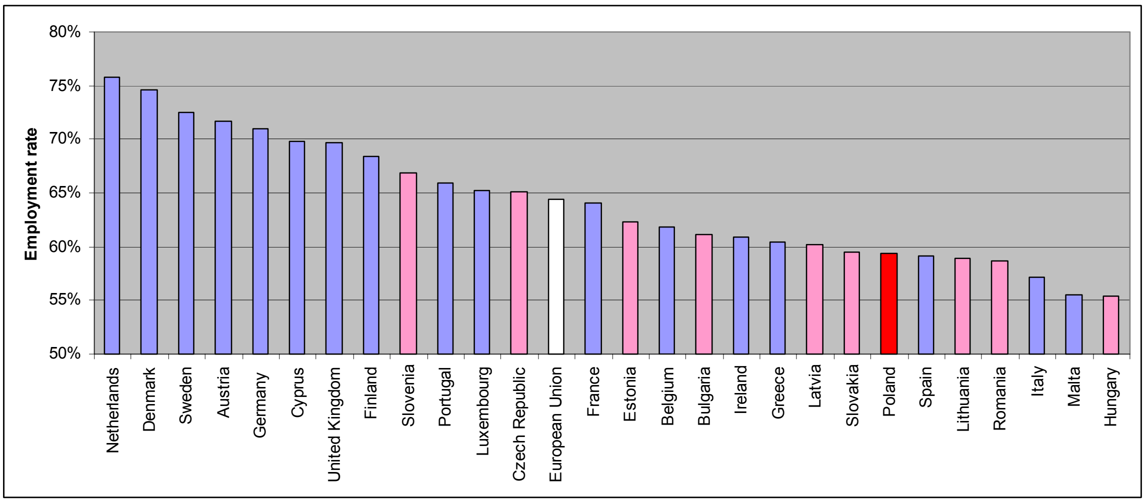

Figure 2-8: Employment rate, Poland vs. EU27 (average for 2009-2010)

Source: Eurostat

In addition, another relevant side of the labour market closely connected with the demographic structure of the country is potential threat to the balance of pension funds related to the demographic changes occurred in Poland in the last twenty years and foreseen for the next decades. In the years 1990-2007, the percentage of population aged below 14 years decreased almost by half, while the percentage of people aged 65 and above increased by more than 3%. Besides, projections indicate until the year 2030 Poland will encounter two important demographic challenges: depopulation and ageing of its population. Both are result of the increasing imbalance between the decreasing number of births and increasing number of deaths coupled with a gradual increase in life expectancy. In the period 2010-2015, Eurostat and GUS (Polish Central Statistical Office) forecasts suggest a moderate increase in the proportion of elders versus working age population. In the next years this process will significantly accelerate, which means that if nowadays there are 2,6 working age persons per person in retirement age, in the year 2030 this proportion may become less than 1,5. A similar trend is shared by most other EU countries (Kancelaria Prezesa Rady Ministrów, 2009).

Recognizing the challenges that lie ahead of EU economies, the European Commission is maintaining as key target of its Lisbon Strategy for Growth and Jobs the need to achieve a 75% employment rate for the 20 to 64 population by 2020. This combines with a number of other targets, including the 20% increase in energy efficiency also expected for 2020. As this study attempts to bring forward, synergies between both policy goals exist and can be realized through the deep retrofitting of the Polish building stock.

3 Research aims and scope

3.1 *The public policy rationales: improving the efficiency of the Polish building stock*

The scale of the proposed buildings energy efficiency programme and the variety of benefits to be accrued makes the State a key actor in the definition and implementation of the retrofits envisioned in this study, without disregarding the importance of the private sector involvement. From a public policy perspective, these range of positive outcomes, which are related to the challenges outlined in Section 2, offer decision-makers strong arguments for a large-scale building refurbishment programme as a key integrated climate change, employment, social welfare and energy policy strategy. More in particular, the following positive outcomes have been identified.

First and foremost, given the poor state of Poland's labour market, with one of the lowest employment rates of the EU27 (see **Section 2.3**), the amount of additional direct, indirect and induced jobs to be created is the key benefit of the proposed intervention. As presented in **Section 7.5** (comparison of employment results with the literature), investing in buildings' energy efficiency –as well as in other mitigation options, like renewable energy – has a proven job-creation record. In that context, the aim of this research is to estimate the extent of the program's positive net employment impacts as well as to explore the additional qualitative effects on Poland's labour market (e.g., composition and geographical distribution of the additional jobs created).

Second, it would help Poland and the European Union to meet the targets of achieving a 20% reduction in primary energy use by 2020 as defined by the EU climate and energy package (*20-20-20* targets). It would ensure that Poland meets the even an ambitious GHG mitigation target (30% by 2020) at the EU level. Additionally, a large scale retrofit as the one proposed may curb perceptibly Poland's total GHG emission levels and increase the amount of available Assigned Amount Units (AAU) to be used in Green Investment Schemes in which Poland has already gathered some experience (Tuerk et al., 2010).

Third, the large scale retrofit programme would substantially reduce the emission of non-GHG pollutants (namely NO_x, SO_x, PM and NMVOC) that have significant negative effects on the human health and ecosystems of Poland. This is particularly relevant because Poland is one of the few remaining coal-based economies of the world (Suwala, 2011) and coal emission intensities for those pollutants are hundred of times higher than those natural gas and district heating (see **Section 8.4.2**). This improvement in the air quality of urban settlements can be improved if the retrofits are implemented along with a progressive phase-out of the use of coal in buildings.

Fourth, the proposed intervention would greatly reduce fuel poverty rates (as an average for 2005-2010, 22% of the Polish population declared not to be able to afford to keep their home adequately warm and 17% declared to be in arrears on utility bills – see **Section 2.1**). More in general, the intervention is expected to greatly reduce the energy costs of households and public building managers in the long-term and would contribute to improve the comfort of buildings users – increased protection against outdoor noise, better indoor air quality, etc. – and to enhance the rental and selling price of properties.

Fifth, a certain reduction of the nation's energy dependency of imported fossil fuels can be expected (see estimates in **Section 6.2**). This is particularly the case of natural gas; although it only contributes to 8.2% of the energy used for space and water heating in Poland's buildings, it is mostly imported (69% of the domestic natural gas consumption). Eventually, the implementation of the programme may help to avoid part of the large, costly infrastructural developments needed for expanding the supply capacity of the country for diversifying its sources of natural gas.

Sixth, the State budget may benefit from the programme: i) directly, in the form of energy savings achieved in public buildings (this might have a small effect at the national level, but could certainly alleviate the finances of local administrations); indirectly, through increased tax collection, reduced unemployment and social benefit payments, etc. However, a decrease in energy tax revenues and increase in government expenditure for financing the programme (depending on the actual financing scheme and number of renovations per year) should also be noted.

3.2 The focus of the research: employment benefits of a large-scale deep energy retrofit programme in Poland

While climate change is often low on real political agendas in medium welfare economies, especially those hit particularly hard by the economic crisis, other policy targets, especially in an integrated manner, may provide strategic entry points to policy- making for important climate change mitigation priorities. This is particularly the case for the refurbishment of inefficient building stocks, since this area is especially hampered by market barriers, and, while cost-effective, its typically long payback times make it unattractive for single policy goals such as mitigation.

Because of the employment benefits of renovation programmes, net job creation may provide a key missing rationale and entry point to Poland's policy-making and effectively facilitate the adoption of a large-scale building energy-efficiency retrofit programme. The deep renovation of Poland's building stock is expected to have a consistent impact on employment; first directly, by the creation of many new jobs in the construction industry. Indirectly, on all the sectors that supply materials and services to the construction industry itself. In addition, the savings caused by the reduction in energy consumption, plus the additional consumption fuelled by the wages of the additional jobs created, will increase the disposable income of the families; income that, when spent, will generate additional induced benefits to employment. On the other hand, it has to be acknowledged that the lower consumption of energy will cause a number of jobs to be lost in the energy supply sector. Besides, some negative employment effects could be also expected if the financing of the programme results in substantial changes in the State's budget, though these have not been estimated.

In this context, the objective of this research is to gauge the net employment impacts of a large-scale deep building energy-efficiency renovation programme in Poland. To do so, the project has been defined within the following boundaries that define the scope of the research:

- Geographical. The Polish stock of buildings and labour market, although some brief considerations were made about the inflow of foreign workers that may be by the programme if implemented to its full extent (see **Section 8.2.1**).

- Type of buildings subject to renovation. The whole existing residential and public buildings stock of the country, which covers most of the constructed floor of the country. Industrial and commercial buildings are left aside, although it may be that a fraction of the latter is included by default as they are embedded in the residential fabric. New buildings have not been considered in general except in the policy recommendations of **Section 9.2**).

- Type of renovation. The refurbishment proposed focuses on reducing the energy needed for space and water heating purposes, leaving aside other uses such as lighting or powering domestic. Heat is believed to be the most energy- demanding end-use of households and public buildings. Several scenarios with different energy saving potentials and implementation rates have been defined (see **Section 5.1.1**).

- Type of employment effects: estimates of the direct, indirect and induced effects have been produced. The employment effects related to the maintenance of the planned deep and sub-optimal renovations have not been calculated because of the uncertainty about how the improvements implemented in the programme would be refurbished at the end of their lifetime and because its effects would be felt in the long run, by the time the model becomes more unreliable.

As a result, this final report provides an estimate of the various employment impacts identified, considering all key factors, and can serve as a guide to strategic policy decisions. It incorporates the comments to an earlier version provided by a number of selected national experts in two workshops held In Warsaw and Katowice in the context of this project. To the research team's knowledge, no similar calculations have been produced up to date for Poland at nationwide or even smaller scales.

This report is being produced in the framework of the European Climate Foundation (ECF) Energy Efficiency programme, in particular the "energy efficiency in buildings" strategic initiative pursued by the ECF. It draws upon the buildings and employment model and methodology used for the previous study conducted on behalf of ECF for Hungary in spring 2010 (Ürge-Vorsatz et al., 2010).

3.3 The research team

The Center for Climate Change and Sustainable Energy Policy (3CSEP) is an interdisciplinary research and educational center at the Central European University (CEU). Energy efficiency in buildings and related social, economic and policy research is at the core of 3CSEP's research activities. Based in Hungary, the Center has completed various studies on the energy and carbon saving potentials of the Hungarian building sector, some of which have successfully influenced high-level national policy-making processes, such as the study on the employment effects of large and deep renovation programme of Hungary's building stock (Ürge-Vorsatz et al., 2010), the predecessor of this study for Poland. 3CSEP is and has been involved in a number of global energy-related research initiatives and projects.

The 3CSEP research team is led by Prof. Diana Ürge-Vorsatz, coordinating lead author of IPCC's 4th and 5th assessment report chapter on mitigation in buildings and convening lead author of the Global Energy Assessment. In addition, the Polish Foundation for Energy Efficiency (*Fundacja na rzecz Efektywnego Wykorzystania Energii* – FEWE) has played a key role in providing data on Poland's building stock, cost of retrofits and energy prices, as well relevant information on the Polish energy policy. Finally, Polish national experts in the fields of labour market and the construction policy/industry were contacted to contribute to the study.

3.4 Structure and rationale of this report

After **Section 1** (technical summary), **Sections 2** and **3** and provide the background, justification, aims and scope of the research. **Section 4** offers a preliminary account of the employment effects usually considered in estimating the employment effects of investment projects, which is the base for the methodology described in **Section 5**. **Section 6** offers a detailed account of the results obtained for the five scenarios considered (*S-BASE*, *S-SUB*, *S-DEEP1*, *S-DEEP2* and *S-DEEP3*) relative to investments, energy savings and avoided CO_2 emissions, while the employment effects for all scenarios are presented in **Section 7**. **Section 8** deals qualitatively with a range of issues of the economy-wide effects of the proposed intervention (geographical distribution and composition of the new jobs, effects on labour supply and wages, etc.). **Section 9** presents the main conclusions, policy recommendations and identifies further research needs based on the limitations encountered.

4 Overview of the employment implications of renovation programmes

A first step taken in this study was to draw a map of the different pathways of employment effects of the proposed programmes as well as a typology of the categories of employment affected. This is the base for the methodological approach employed for the estimation of the net employment effects.

Typically, three employment effects of investment programmes have been described in the literature (Weber, 1998; Geller et al., 1998; Bailie et al., 2001). For the case of a buildings energy efficiency intervention, they are described as follows:

- Direct employment effects, which happen as a result of an increase in the output of the construction sector, the one actually implementing the retrofits and improving the energy performance of buildings.
- Indirect employment effects are a result of the increase in the demand of goods and services produced by sectors that supply those directly involved in the intervention (e.g., transport, catering, materials, etc).
- Induced employment effects will take place only when the intervention starts producing the desired effects. Since the energy savings produced by the investments will increase to a certain extent the available income of households and public building managers this will create an increase in the demand of other goods and services, and therefore enhance the employment in the related sectors. Induced effects also include the results of the additional income obtained by the new workers of the intervening sectors (Pollin et al., 2009b).

Climate interventions such as energy efficiency retrofits in buildings usually increase the demand of goods and services supplied by certain sectors (e.g., construction and renovation) and decrease the demand of goods and services supplied by others (e.g., energy generation and distribution). This means that both job creation and destruction processes will take place, and that an estimate of the net employment effects has to be obtained. Direct, indirect and induced effects are expected both on the job-creation and job-destruction sides, as depicted in **Figure 4-1**.

Besides, additional negative employment impacts may occur if the renovation programme reduces government's expenditure – depending on how the programme is actually financed – on other areas or if it results in decreased energy tax collection. The analysis of the latter issues remains beyond the scope of this study not only because financing issues have purposely not been dealt with, but also because they would require a comprehensive analysis of the wide macroeconomic effects of the intervention with more advanced methodologies such as Computable General Equilibrium Models.

Błąd! Nie zdefiniowano zakładki.

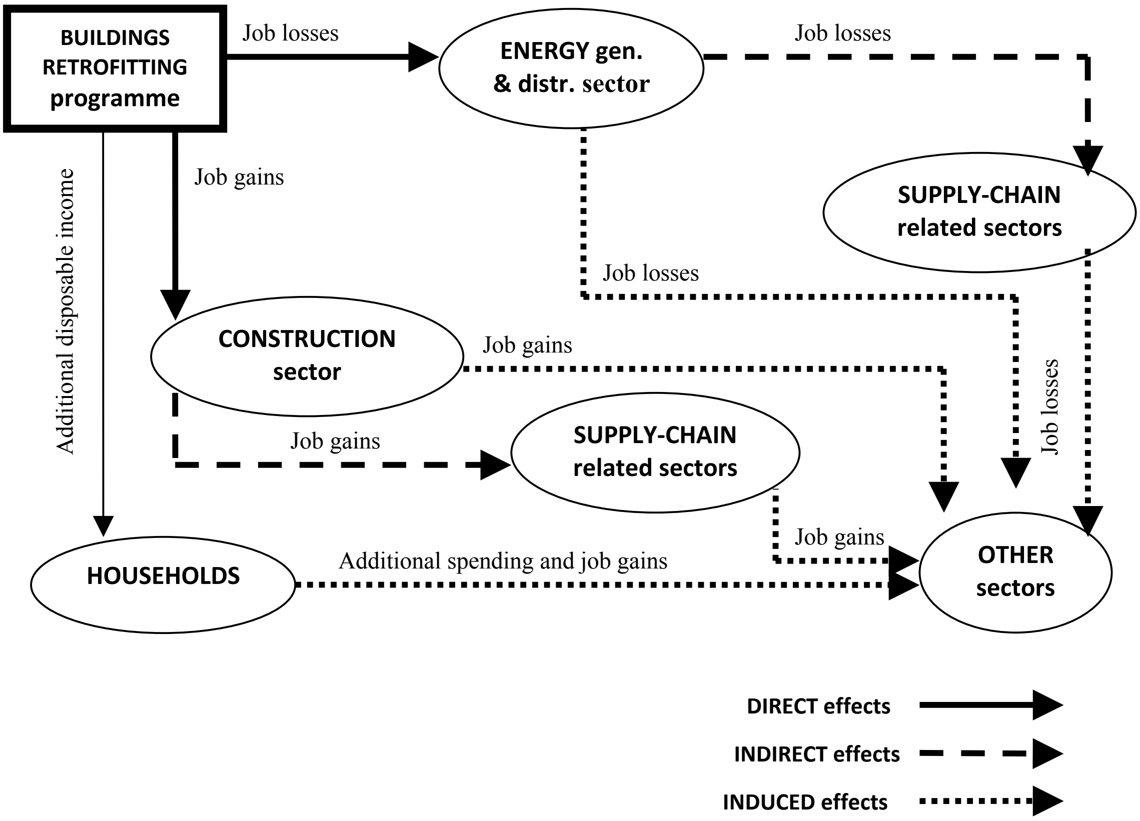

Figure 4-1: The chain of effects on employment of the proposed intervention

In addition, the following employment implications of all studied scenarios have been considered (see **Section 8** for a detailed discussion):

- Geographical distribution of employment effects. While examining the nationwide effects of an investment programme, it must be noted that some employment impacts are spatially distributed (the programme creates local jobs, e.g. the installation of the insulation) and some other are centralised (a number of new jobs are created in a central location, e.g. the production of the insulation materials). Some of the latter jobs, particularly in manufacturing, can be exported abroad (see **Section 8.1.1**).

- Temporal durability of employment effects. An investment programme will usually create two types of jobs: short- and mid-term jobs, which exist while the programme is active, and more permanent positions that remain after the end of the programme. While this distinction is important in short-term programmes (e.g., the organisation of events, such as the Olympic Games), the renovation of the whole Polish building stock will take decades. Consequently, the labour demand shift can be considered permanent for the period of analysis (see **Section 8.1.2**).

- Composition the of new employment. The programme will increase the demand for all skill levels in the construction sector: there will be effects on the professional workforce (such as architects and engineers), on the skilled workforce (e.g., plumbers, electricians and painters) and on the unskilled workforce. An estimate of the skill-level composition of the direct employments created in the construction sector based on data gathered from actual renovation projects is presented in **Section 7.1**. The gender and age composition of the employment created is also discussed in **Section 8.2.1**.

- Effects on the labour market. Given the large scale of the proposed intervention, significant changes – commensurate to the amount of additional jobs created – are expected to take place in the construction sector and others sector affected by the intervention, influencing labour supply and even wages. These elements have to be taken into consideration, especially when deciding on the implementation rate of the programme. The study also discusses the issue of the informal economy because a certain fraction of Poland's labour market is thought to be grey labour (see **Section 8.2**)

- Effects on other sectors. In order to have a net estimate of the aggregate employment effects of the program, job losses in negatively affected sectors (namely energy suppliers and its supply-chain related sectors) must be accounted for. The estimation model incorporates this consideration, and additional aspects such as the rebound effect are discussed in **Section 8.3.1**. Besides, the influence of the intervention on the manufacturing sector are briefly discussed in **Section 8.3.2**).

- Financing. Different options could be considered for the actual financing of the program, which could have an influence on the amount and composition of jobs created. Among those, a basic assumptions about how the investment costs of the retrofits are met (i.e., a *pay-as-you-save* scheme that gives back 20% of the savings to households/public buildings managers based on a zero interest rate credit offered by the State) has been included for the estimation of employment impacts. In general, financing issues have been considered to be beyond the scope of this research and thus have been deliberately kept aside; however, a range of financing tools with a potential to leverage the large capital needs identified is presented and discussed in **Section 8.5**.

- Additional benefits. Namely, the fuel poverty alleviation benefits, the mitigation of non-GHG emissions, the increase rental and resale price of properties and the fiscal effects of the intervention are discussed in **Section 8.4**.

- Applicability of the results to other EU Member States. Provided that there are certain similarities among Central and Eastern European (CEE) Member States in terms of their labour market, economic performance and energy inefficiency of their building stock, the results of this research series (Hungary and Poland) provides a certain ground for further studies in the region (see **Section 8.6**).

5 Methodology

5.1 Methodology used for modelling the renovation scenarios

5.1.1 Scenarios considered

The long and short-term employment impacts of a building renovation programme depend on its scale and schedule. Accordingly, this study explores the employment impacts of five building renovation scenarios – one *business-as- usual* (*S-BASE*) and four intervention scenarios (*S-SUB* and *S-DEEP*) – with different building stock renovation rates and intensities. They are summarized in **Table 5-1**, with further information on renovation rates provided in **Section 5.1.4**. Scenarios are graphically represented in **Figure 5-1**,which shows the annual number of units retrofitted (in dwelling-equivalent that account for both public and residential buildings) and the ramp-up period through 2081. **Figure 5-2** displays the cumulative floor area, in square meters, renovated under each scenario throughout the same period.

Name	Scenario	Retrofit rate	Type of retrofits	Forecasted completion
S-BASE	**Baseline** scenario with current subsidies	**3% of the non-renovated stock in 2010** - 25 million square meters or 310,000 dwellings per year	*Business-as-usual* thermo-retrofits	33 years
S-DEEP1	**Deep** retrofit with slow implementation rate	**1.5%** - 16 million square meters or 195,000 dwellings per year	Deep retrofits	68 years
S-DEEP2	**Deep** retrofit with medium implementation rate	**2.5%** - 26 million square meters or 320,000 dwellings per year	Deep retrofits	42 years
S-DEEP3	**Deep** retrofit with fast implementation rate	**3.5%** - 36 million square meters or 450,000 dwellings per year	Deep retrofits	31 years
S-SUB	**Suboptimal** retrofit with medium implementation rate	**3% of the non-renovated stock in 2010** - 25 million square meters or 310,000 dwellings per year	Suboptimal retrofits	33 years

Table 5-1: Retrofit programme scenarios

<u>Baseline Scenario, ***S-BASE***</u>. In this scenario dwellings are renovated at a *business as usual* rate of 3% of the non-renovated building stock in 2010 per annum (see **Section 5.1.4**). The reduction in the energy consumption for space and water heating in each building class is about 30%. Since this scenario basically represents a continued implementation of the Polish

Thermo-modernisation programme (see **Section 2.2.3**), buildings that have been retrofitted to some level (either within or outside the Thermo-modernisation programme), which account for 20% of Poland's building stock, are excluded from this scenario. It is assumed that measures typically implemented through retrofits supported by the Thermo-modernisation programme retrofits deliver a 30% reduction in energy consumption .

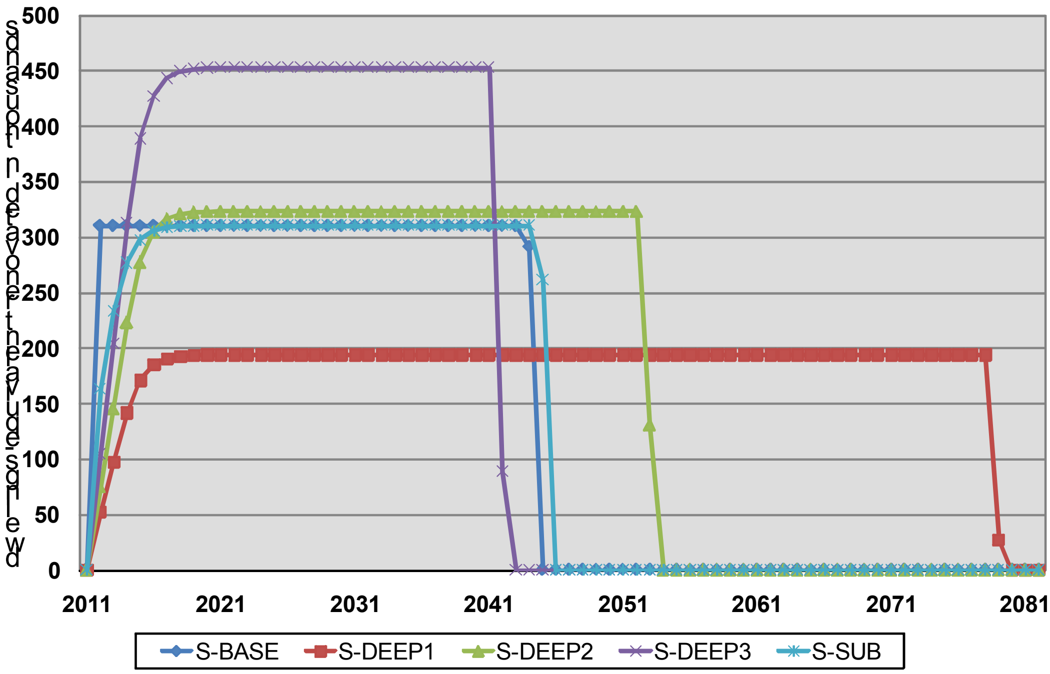

Figure 5-1: Number of dwellings-equivalent renovated per year

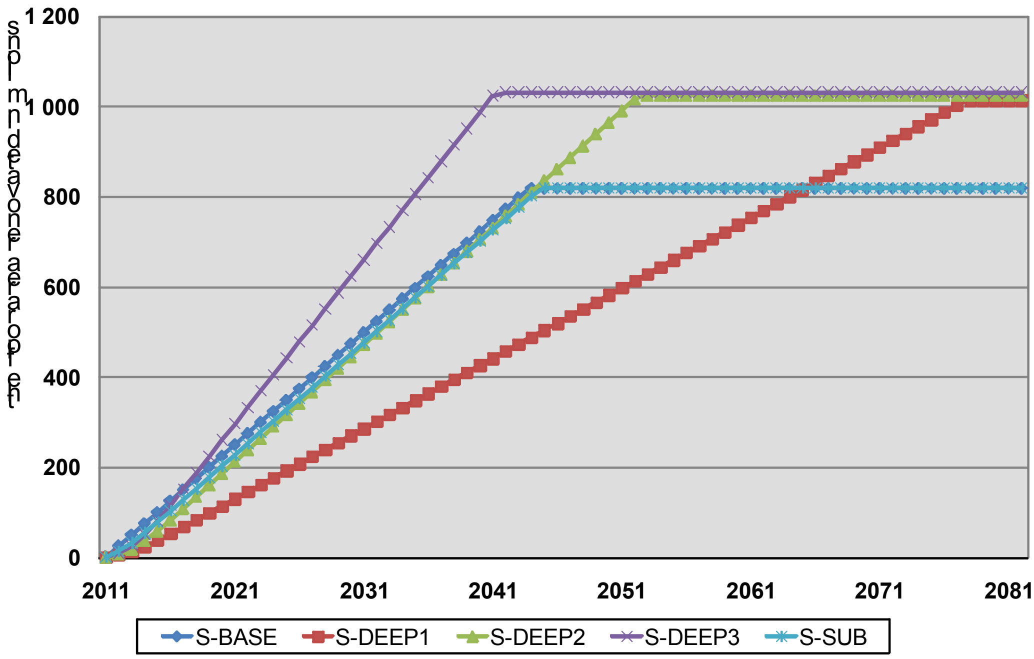

Figure 5-2: Cumulative floor area renovated under each scenario

Deep Retrofit and Slow Implementation Scenario, ***S-DEEP1***. In this scenario, a renovation rate of 1.5% per annum, or 195,000 dwelling-equivalents, is assumed. Energy savings are 75% to 90% of the original building energy consumption for space heating and hot water.

These types of energy savings are obtainable through holistic building renovation approaches that eliminate the need for costly central heating equipment. One example of these deep energy retrofit approaches is the *passive house* design as elaborated by Dr. Wolfgang Feist and Prof. Bo Adamson. The passive house standard, as applied to building renovations, requires an energy consumption of 15 kWh/m2/year in residential buildings and 30 kWh/m2/year in public buildings. Given that achieving such ambitious energy standard is difficult in a existing building, the model assumes that deep retrofitted units achieve a level of 50 kWh/m2/year. This represents saving between 64% to 89% as compared to the per square meter space and water heating energy consumption before retrofit (depending on building typology: some are initially more effieinct than others). Such a low level of energy consumption is usually obtained by insulating the building extensively, ensuring the air tightness of the building, and installing a heat recovery ventilation system.

Deep Retrofit and Medium Implementation Scenario, ***S-DEEP2***. In this scenario, a more ambitious renovation rate of 2.5% per annum, or 320,000 dwelling equivalents, is assumed. Savings are likewise 64% to 89% (depending on the building typology) of the original building energy consumption including hot tap water.

Deep Retrofit and Fast Implementation Scenario, ***S-DEEP3***. In this scenario, the most ambitious rate of renovation (3.5% of total floor area per year or 450,000 dwellings equivalent per year) is applied while the same savings of 64% to 89% (depending on the building typology) of the original building energy consumption, including hot tap water, are assumed.

Suboptimal Scenario, ***S-SUB***. In this scenario, the rate of renovation is the same as in *S-BASE*, though more strict energy renovation standards are applied. Buildings already retrofitted to some level (either within or outside the Thermo-modernisation programme), which account for 20% of Poland's building stock, are excluded from this scenario. Savings of 50% from original building energy consumption are achieved.

5.1.2 Major assumptions for all scenarios

This study focused on existing residential and public sector buildings, excluding commercial buildings (offices, retail etc.). The former are believed to contain the bulk of the efficiency potential in the Polish building sector and are therefore where policy intervention is most warranted. Retrofitting these two building sector components is likely to have higher social benefits, due to the improved social welfare of individual households (i.e., better thermal comfort, reduced fuel poverty rates, improved air quality in urban areas, etc.) and individual taxpayer savings on public building energy bills. In addition, it is believed that commercial buildings are relatively new and thus more energy efficient and that commercial building owner have access to the capital markets needed for retrofits, if deemed profitable. Accordingly, there is less need to mobilize public support for policy intervention in the commercial building sector. Moreover, commercial building stock is highly fragmented, and data on this building sector component is less accessible than is the case for residential and public sector buildings.

The potential employment benefits of several scenarios were analyzed so that policy decisions could be compared with the costs and time scales of different rates of renovation of the building stock. In this regard, the business as usual scenario (*S-BASE*) was included so that the intervention scenarios could be effectively compared with the retrofits currently carried out by individual households and public building managers in Poland. Then, *S-SUB* scenario provides a non-state-of-the art alternative for an intervention scenario, which is likely to be adopted if not very ambitious energy and climate goals are pursued. It has been included in to assess the impact of the *lock-in* effect by comparing its results with the results of deep renovation scenarios (see below). Finally, the three scenarios where a deep energy renovation of the Polish building stock is considered (*S-DEEP*) offer an ambitious alternative to decision makers in terms of the energy savings, emission reductions and fuel poverty reduction achieved. These retrofits, unlike piecemeal approaches to energy savings that consider only individual component impacts, entail a large upgrade of the building ventilation system and thermal envelope. The latter is of critical importance to overall building energy consumption since it is primarily responsible for keeping occupants dry, warm, comfortable, and healthy. It is therefore essential that all components of the building envelope, such as levels of insulation, thermal bridges, and windows, be selected in an integrated manner to optimize its overall performance.

The baseline scenario serves thus as a reference for the analysis of the other scenarios. Therefore, when estimating the additional effects of each of the four intervention scenarios (*S-SUB* and the three *S-DEEP*), the results of the model for the *S-BASE* scenario need to be taken into account, e.g., the additional employment and energy saving generated by *S-DEEP1* scenario must subtract the results for *S-BASE* scenario to the results obtained for *S-DEEP1.*

Additionally, public building managers have been assumed to behave in a similar way as households: they manage a fixed amount of funds allocated by the central or local government, invest in an energy-efficient retrofit (through loan financing where necessary), and directly reap the benefits of reduced energy bills.

5.1.3 Types of retrofits covered in the scenarios and the risk of the *lock-in* effect

This research has focused on scenarios *S-DEEP1*, *S-DEEP2* and *S-DEEP3*, which assume that the programme will support deep building retrofits. The aim is to bring the buildings as close to passive house standards (i.e., a space heat consumption of 15 kWh/m2/year) as it is economically feasible. The reason for this assumption is the risk of the *lock-in effect*, which is explained as follows. If a massive renovation programme *cherry-picks* by harvesting only the lowest hanging fruit (implements only those energy efficiency measures with the shortest payback period, like replacing windows or partially improving building insulation), this will impair Poland’s ability to meet the long-term, more ambitious emission reduction targets that are likely to be requested in the long term. This is because if a building has already undergone a renovation, it is cost-inefficient to undergo yet another renovation to capture the remaining, non-captured energy efficiency potential. Therefore, a suboptimal retrofit, even achieving a 50% reduction on the previous energy consumption, will *lock in* a large fraction of current building (and national) emissions for several decades. This would jeopardize Poland's potential to achieve an ambitious GHG reduction target by 2050, since heating-related emissions are difficult to mitigate other than by addressing them in the buildings themselves.

In the Central and Eastern European context, it is know that the use state-of-the art retrofitting know-how, such as that demonstrated by the SOLANOVA pilot project in Hungary (Hermelink, 2007), would allow reaching ambitious GHG reduction targets. The SOLANOVA project, which reduced space heating energy consumption and emissions by up to 80% - 90%, compares favorably with the significantly lower energy savings achieved by other State-funded building energy efficiency initiatives like the Thermo-modernisation programme. Based on this comparison, there exists a definite risk that state-sponsored programs' continued application of suboptimal technology will lock-in the substantial energy saving potential of Poland's building stock for decades.

Therefore, while the focus of this research has been on a deep retrofit renovation programme, this study has also examined a future policy scenario, *S-SUB*, in which suboptimal renovations would instead be state-supported. Another aim of this study is to compare the employment and energy savings impacts of *S-SUB* to each of the deep renovation scenarios.

5.1.4 Renovation rates

The baseline scenario, *S-BASE*, assumes that no renovation programme will be applied, with renovations thus following a *business-as-usual* pattern. The retrofits of the buildings and the rates of renovation would not differ from current trends.

Renovation rates for *S-BASE* and *S-SUB* scenarios are based on the energy audit database carried out and verified by FEWE and GUS data (Local Data Bank) demonstrate that 3% of Polish buildings are renovated by the Thermal Modernisation programme annually. This corresponds to roughly 310,000 dwelling-equivalents (residential and public units), or 25 million square meters of floor area, per year. This rate only applies to the 80% of non-renovated Polish building stock (i.e., it is equivalent to a rate of 2.4% if measured against the 100% of the building stock). This renovation rate is somewhat higher than the rate assumed in other studies for the region: Novikova (2008) assumes a 1% renovation rate; Janssen (2010) presents a rate of 1.2 – 1.4% for EU countries; Petersdorff et al. (2004) assume a 1.8% rate for the EU-15; and Lechtenböhmer et al. (2009) assume a 1% natural renovation rate and a 2.5% accelerated rate for the EU-27. A likely reason for this is the State-supported Thermal Modernisation programme, which speeds up the *natural* rate of retrofits.

The renovation rates for the scenarios considered in the model are as follows:

1. ***S-BASE***. An average renovation rate of 25 million square meters of floor area per year

(equivalent to 310,000 dwellings), corresponding to 3% of the non-renovated Polish building stock in 2010 (80% of the total floor area). The total building stock would be renovated in 33 years, taking the cessation of old units into account.

2. ***S-DEEP1***. An average renovation rate of approximately 16 million square meters of floor area per year (equivalent to 195,000 dwellings), corresponding to 1.5% of the total floor area considered. The total building stock would be renovated in 68 years, taking the cessation of old units into account.

3. ***S-DEEP2***. An average renovation rate of approximately 26 million square meters of floor area per year (equivalent to 320,000 dwellings), corresponding to 2.5% of the total floor area considered. The total building stock would be renovated in 42 years, taking the cessation of old units into account.

4. ***S-DEEP3***. An average renovation rate of approximately 36 million square meters of floor area per year (equivalent to 450,000 dwellings), corresponding to 3.5% of the total floor area considered. The total building stock would be renovated in 31 years, taking the cessation of old units into account.

5. ***S-SUB***. The renovation rate is the same as in the *S-BASE* scenario, namely, 25 million square meters of floor area per year (equivalent to 310,000 dwellings), corresponding to 3% of the non-renovated Polish building stock in 2010 (80% of the total stock. The total building stock would be renovated in 33 years, taking the cessation of old units into account.

5.1.5 Ramp-up period

Even though annual renovation rates for *S-DEEP1* and *S-DEEP2* scenarios are below or similar to the baseline renovation rate reported for *S-BASE*, it is unlikely that the Polish construction industry will be capable to immediately provide an output of 16, 26 or 36 million square metres retrofitted per year of deep retrofits because of their higher technical complexity. For this reason, a time period must be allotted to allow for adjustments in the market. Accordingly, an S-shaped ramp-up period of 5 years was assumed, during which industry players are expected to become familiar with the applicable technologies and acquire the necessary resources and experience to upscale their businesses. (The S-shaped ramp-up period models the initial stage of growth as approximately exponential, up to the point of saturation). The same ramp-up period also applies to the *S-SUB* scenario.

5.1.6 Poland's building stock

The Polish residential and public building stocks have been modeled as ten different building types, which are the same for both sub-sets (see **Table 5-2** and **Table 5-3**). Although the structure of public buildings are similar to that of the residential, public building functions vary widely as they host educational, governmental, medical, cultural, social, etc. activities, which has an impact on their energy consumption. Due to a lack of available data, this study does not analyse public buildings in Poland according to their function but makes them equivalent to the residential building typologies (though public buildings have lower specific energy consumption). This assumption introduces a certain error in the estimates, which is expected not be too significant. In the end, the public building stock represents less than 16% of the total floor area considered in the model and consumes just over 10% of the total energy for space and water heating for the combined public and residential sectors.

RESIDENTIAL BUILDINGS	SINGLE FAMILY					MULTI-FAMILY				
	before 1918 historic buildings	**1918 - 1944**	**1945 - 1970**	**1971 - 1988**	**1989-2010**	**before 1918 historic buildings**	**1918 - 1944**	**1945 - 1970**	**1971 - 1988**	**1989-2010**
Total Number of Dwellings (thousands)	423	589	1108	1773	1323	636	885	1665	2664	1988
Total Number of Dwellings heated (thousands)	418	582	1094	1750	1306	627	874	1644	2629	1962
Total heated floor area of building type (millions of sqm)	39	55	103	166	124	31	44	82	132	98
Fraction of Residential/Public Number of Dwellings	5%	6%	12%	19%	14%	4%	5%	9%	15%	11%
Fraction of Total Number of Dwellings	3%	4%	8%	14%	10%	5%	7%	13%	20%	15%
Fraction of Total Building Floor Area	4%	5%	10%	16%	12%	3%	4%	8%	13%	9%
Characteristics of buildings										
Total Number of Dwellings ceased per year	881	881	78	78	39	823	823	73	73	37
Ceased sqm per year (thousands)	83	83	7	7	4	41	41	4	4	2
Avg. # of Dwellings Per Building type	1	1	1	1	1	17	17	17	17	17
Avg. Floor Area of Dwelling (m2)	95	95	95	95	95	50	50	50	50	50
Avg. Floor Area of Building (m2)	103	103	103	103	103	836	836	836	836	836
Building space and water heating characteristics (current building stock)										
Specific Energy Requirement (kWh/m^2/a)	456	380	347	302	262	322	258	228	203	182
Fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total space heating energy requirement (twh/a)	14	16	27	37	24	8	8	14	20	13

Table 5-2: Characteristics of the residential building stock in Poland

Source: Census 2002, GUS Local Data Bank

PUBLIC BUILDINGS	SINGLE STOREY					MULTI STOREY				
	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010
Total Number of Dwellings (thousands)	2	3	5	8	6	3	4	7	12	9
Total Number of Dwellings heated (thousands)	2	3	5	8	6	3	4	7	12	9
Total heated floor area of building type (millions of sqm)	1	1	3	4	3	12	17	32	52	39
Fraction of Residential/Public Number of Dwellings	0.6%	0.9%	1.6%	2.6%	1.9%	7%	10%	20%	31%	23%
Fraction of Total Number of Dwellings	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%
Fraction of Total Building Floor Area	0.1%	0.1%	0.3%	0.4%	0.3%	1.2%	1.7%	3.1%	5.0%	3.7%
Characteristics of buildings										
Total Number of Dwellings ceased per year	4	4	0	0	0	62	62	6	6	3
Ceased sqm per year (thousands)	2	2	0	0	0	270	270	24	24	12
Avg. # of Dwellings Per Building type	1	1	1	1	1	1	1	1	1	1
Avg. Floor Area of Dwelling (m2)	534	534	534	534	534	4334	4334	4334	4334	4334
Avg. Floor Area of Building (m2)	534	534	534	534	534	4334	4334	4334	4334	4334
Building space and water heating characteristics (current building stock)										
Specific Energy Requirement (kWh/m^2/a)	344	286	261	227	198	243	194	172	153	137
Fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total space heating energy requirement (TWh/a)	0.3	0.3	0.5	0.7	0.5	2	3	4	6	4

Table 5-3: Characteristics of the public building stock in Poland

Sources: Energy audit data scaled to the building model structure

	RESIDENTIAL BUILDINGS	SINGLE FAMILY					MULTI-FAMILY				
		before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010	before 1918 historic buildings	1918 - 1944	1945 - 1970	1971 - 1988	1989-2010
S-BASE	New space heating energy requirements (kWh/m2/a)	319	266	243	211	184	226	180	159	142	127
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
S-DEEP	New space heating energy requirements (kWh/m2/a)	50	50	50	50	50	50	50	50	50	50
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
S-SUB	New space heating energy requirements (kWh/m2/a)	228	190	173	151	131	161	129	114	101	91
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

PUBLIC BUILDINGS		SINGLE STOREY before 1918 historic buildings	SINGLE STOREY 1918 - 1944	SINGLE STOREY 1945 - 1970	SINGLE STOREY 1971 - 1988	SINGLE STOREY 1989-2010	MULTI STOREY before 1918 historic buildings	MULTI STOREY 1918 - 1944	MULTI STOREY 1945 - 1970	MULTI STOREY 1971 - 1988	MULTI STOREY 1989-2010
S-BASE	New space heating energy requirements (kWh/m2/a)	241	200	183	159	138	170	136	120	107	96
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
S-DEEP	New space heating energy requirements (kWh/m2/a)	50	50	50	50	50	50	50	50	50	50
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
S-SUB	New space heating energy requirements (kWh/m2/a)	172	143	131	114	99	121	97	86	76	69
	New fraction of floor area heated	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Table 5-4: Space and water heating characteristics of the Polish building stock after retrofit.

By floor area, the largest category of buildings in the residential stock are the single family homes and multi-family buildings built in 1971-1988). The highest specific energy consumption (456 kWh/m2/year) was recorded for the pre-1918 single family typology. The lowest corresponds to multi-storey public building units built after 1989 (137 kWh/m2/year).

The public building stock energy consumption and floor area is dominated by industrial technology multi-story buildings (see **Table 5-3**). Single story dwellings make up a small portion of the total public building stock (10% of the total floor area considered in this model). For all categories, the specific energy consumption for space and water heating of public buildings is below that of residential buildings (i.e., the model assumes that public buildings use less energy per square meter and year than residential buildings).

The model also assumes that 1% of the Polish residential building stock is unheated (i.e., summer houses, empty dwellings, etc.); these unheated buildings have not been taken into account for the energy-efficient renovation programmes analyzed in this study.

The model assumes, for each scenario, that 0.225% of the total floor area per year of the non-renovated building stock will be ceased. This cessation rate for the existing building stock was determined using historical cessation rates from the GUS Local Data Bank and 2002 Census 2002, and data from the Polish Central Statistical Office. It is assumed to remain the same throughout each scenario, and the retirement of buildings with respect to specific building types is assumed to be linear. Further cessation and renovation stops once the entire building category has *turned-over* to higher energy efficiency levels.

Specific energy requirements and fraction of floor area heated after renovation. The main purpose of the retrofits is to reduce the specific energy requirement for space and water heating. The reduction is commensurate with the intensity of the retrofit, as shown in **Table 5-4**: *BAU* retrofits such as the ones achieved by the Thermal Modernization programme avoid just a 30% of the previous energy use per square meter, suboptimal retrofits halve it and deep retrofits achieve the 50 kWh/m2/a level, the closest to the passive standard reduction which is assumed as feasible. The fraction of floor area heated is supposed to remain the same (75%) before and after renovation, no matter the intensity of the retrofit.

5.1.7 Cost of the retrofits: technology/know-how learning factor

The costs and labour required for a renovation are not fixed throughout the years, especially with respect to the deep renovation scenarios analyzed in this study. This is because Poland's experience with deep renovations is currently extremely limited, as in many other countries. If deep retrofits were implemented to a large scale, firms and individuals will improve their knowledge of energy-efficient retrofit technologies. Moreover, increased demand for building renovations will engender the mass production of building materials. These economies of scale will thus result in lower materials and labour costs. In terms of the model's parameters, this implies that renovation costs will decrease and labor productivity will increase (thus labour intensity will decrease). As labour intensity and costs are directly proportional, this study modeled the learning factor simply through a reduction in costs.

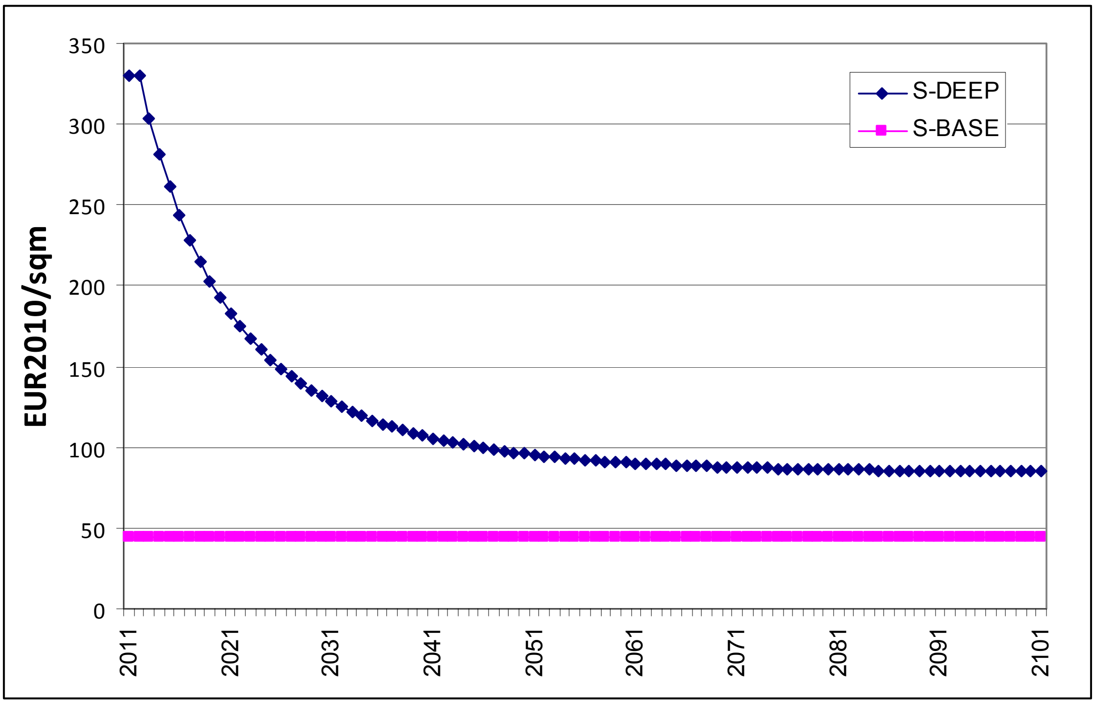

Figure 5-3: Average renovation costs [EUR/m2] for all building typologies, with learning factor

This study assumes that costs for baseline and suboptimal renovations will remain fixed throughout the period considered since these technologies are mature and will not likely benefit from significant cost reductions due to economies of scale. On the other hand, costs for deep renovations are assumed to gradually decrease towards an asymptotic cost equivalent of double the price (per square metre) of a base renovation (as in the Hungarian model – see Urge-Vorsatz et al., 2010), which happens by the year 2070. The evolution of deep renovation costs is illustrated by **Figure 5-3**.

5.1.8 Energy carriers

The mix of energy carriers currently used for meeting the demand of space heating and hot water in Polish residential and public buildings is given in **Figure 5-4**. According the model's data and assumptions, a large fraction of heat effectively delivered to such is provided by coal. In addition, as of 2010 76% of the district heat in Poland was coal-based (Urząd Regulacji Energetyki, 2011). This illustrates the extent of coal reliance for heat production in Poland.

The model assumes that each building typology defined has its own energy carriers split and that a fuel switch does not occur after renovation. The latter assumption was made because a building renovation does not necessarily imply a fuel switch but it rather merely involves an equipment upgrade. However, since different building typologies have different cessation rates and fuel mixes, the composition of the fuel mix after retrofit changes to a small extent.

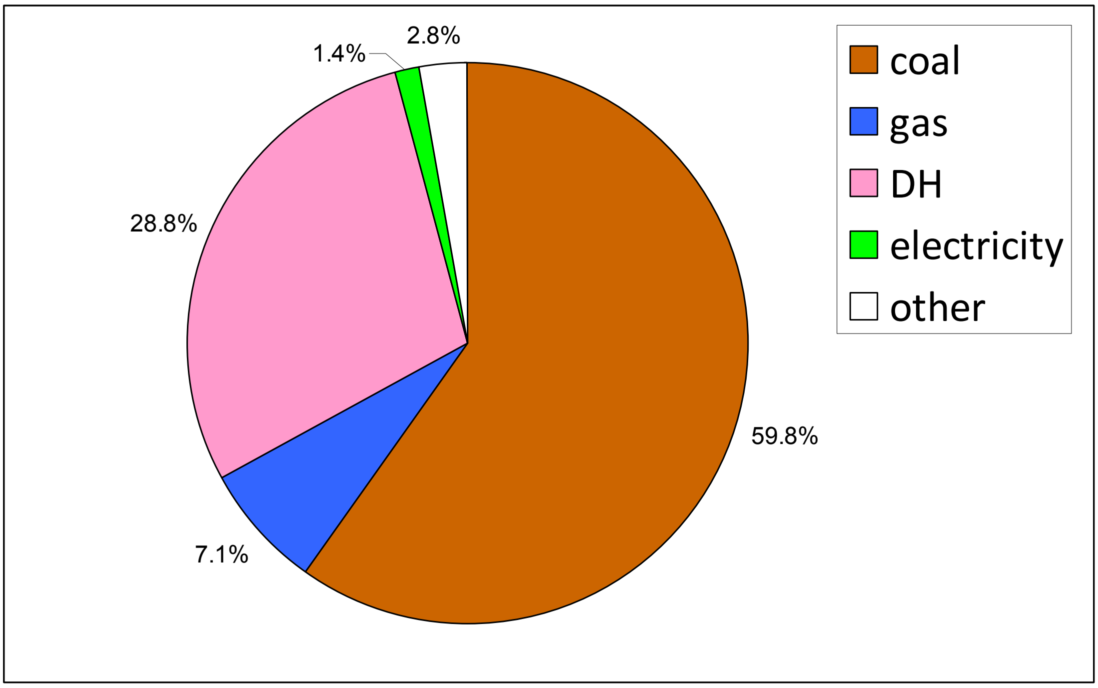

Figure 5-4: Current effective mix of energy carriers for heat of Poland's building stock

Source: Housing Census 2002; Central Statistical Office

5.1.9 Energy prices

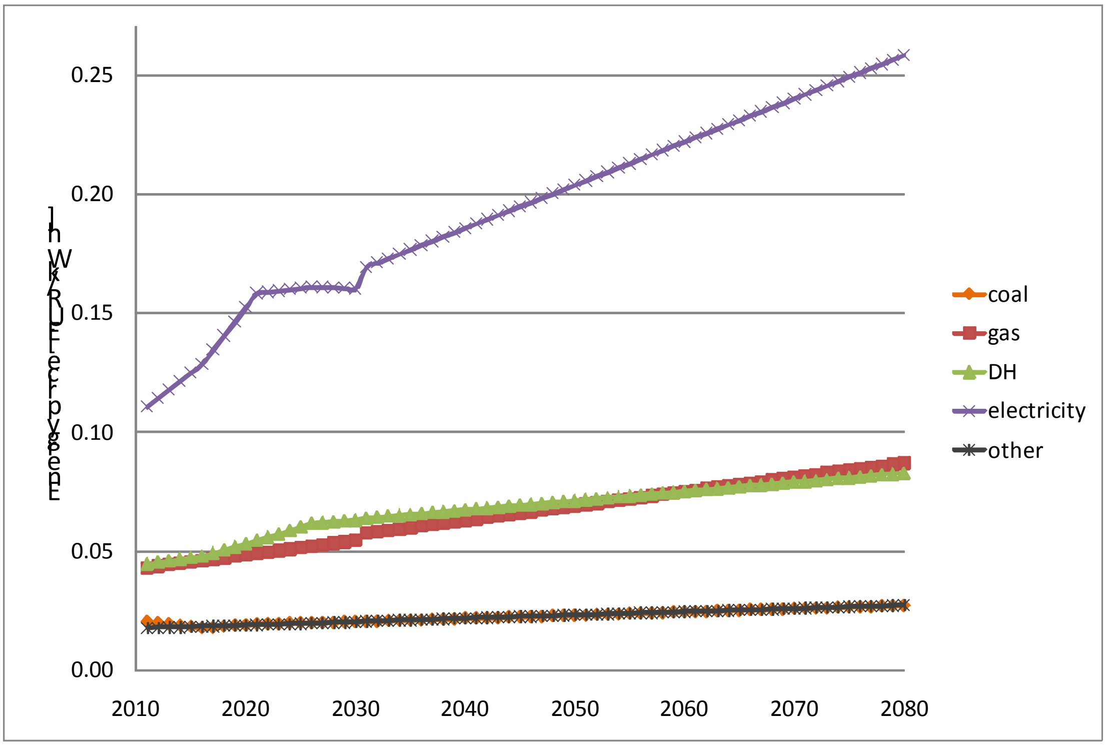

Figure 5-5: Prices of energy carriers and their projected change in real prices

In order to estimate the savings in energy expenditure for building owners and the investment payback period, it is necessary to project energy prices. However, it must be noted that energy prices forecasts carry a certain degree of uncertainty connected to the changing conditions in energy markets.

The current prices of energy carriers in Poland as well as the forecast for their future increase in real terms are presented in **Figure 5-5**. This is based on 2010 energy prices retrieved from the Price Indices of Consumer Goods and Services of the Central Statistical Office (for coal, natural gas and electricity) the Polish Energy Regulatory Office (for DH) and on the energy price projections until 2030 of the document *Energy Policy of Poland until 2030* (Polish Ministry of Economy, 2010). These were then extrapolated through the year 2080.

5.1.10 CO_2 Emission Factors

Since reducing carbon emissions is one of the main purposes of the renovation programmes, CO_2 emission factors for each energy carrier were determined in order to estimate the emissions mitigation potential of the scenarios assessed.

CO_2 emission factors	g/kWh
Coal	470.28
Gas	193.63
DH	390.2
Electricity	791.7
Other fuels	72.88

Table 5-5: CO_2 emission factors

Though emission factors for primary energy fuels do not vary significantly across the globe, especially when accounted for strictly at the site of consumption (i.e., when embodied CO_2 in the extraction and transportation of fuels are not taken into account), data were collected at the national level. Thus emission factors for the mix of energy carriers used in Poland's buildings were calculated based on the heat of combustion data from GUS Energy Statistics for the years 2007 and 2008) and are presented in **Table 5-5**.

The model assumes that emission factors do not vary over time, and that electricity and that district heating technologies remain constant for the duration of each scenario. The latter assumption overestimates to some extent the amount of carbon emissions avoided by the scenarios.

5.2 Methodology used for modelling the employment effects of the scenarios

5.2.1 Overview of the methodological approaches used for estimating the employment impacts

Four main methodological approaches can be considered for the estimation the employment impacts of investment programmes and policy interventions:

Scaling-Up of case studies. In a scaling-up analysis, employment figures from actually completed case studies (see Wade et al., 2000; Jeeninga et al., 1999; Blanco and Rodrigues, 2009; Bezdek, 2009) – are *upsacaled* to the level of the proposed investment intervention (see Wei et al., 2010). Case study job-creation figures are linked to the energy savings, investment, duration and/or scale of the intervention. They are also referred to as analytical methods, usually account only for direct effects, disregarding multiplier effects and thus underestimating overall employment effects (Kammen et al., 2004).

Input-Output (I/O) analysis. Input-Output analysis is the most widely utilized methodology for forecasting the employment impact of changes in the economy, including energy efficiency interventions (see Pollin and Garrett-Peltier, 2007; 2009a; 2009b; Tourkolias et al., 2009). Input-Output tables allow for an analysis of a proposed intervention's impact on the economic activity of all directly or indirectly related sectors. Data on the labour intensity for each sector allow for an estimation of the net employment impacts of the specific intervention proposed. Input-Output analysis can also be used to estimate the induced impacts of a proposed intervention, through an analysis of changes to households' final consumption. It has been criticised because of the number of implicit assumptions underlying the calculations (Kammen et al., 2004).

Computable General Equilibrium Models (CGEM). General equilibrium models capture the complex dynamic effects of policies on a variety of macroeconomic parameters, including employment (Kremers et al., 2002), thus allowing for the incorporation of interactions and feedbacks between sectors and of the existing constraints of production factors (labour, capital, etc.). One recent example of a CGEM study is the European Photovoltaic Industry Association report on the employment impacts of an expanded use of solar PVs for electricity generation (PV Employment, 2009).

Results transfer. In a results transfer approach, researchers rely on the results of previous studies, utilizing the three methodologies described above, to derive net employment effect estimates. One recent example is Greenpeace's report, *Working for the Climate* (2009), which estimates the global employment effects by 2030 of the ambitious adoption of renewable and energy efficiency technologies; the study's results were based on the application of employment factors extracted from the existing literature. The advantage of this approach is its application of reliable data from other markets or locations to areas where little data is available. Nonetheless, differences in economic and market environments subject such results transfers to significant limitations due to differences in the economic and market environments.

5.2.2 Methodological approach used: a combination of up-scaling case studies and I/O analysis.

Like the preceding study in Hungary (Urge-Vorsatz et al., 2010), the model used for the Polish case uses a mixed approach to calculate the employment impacts of energy-efficient retrofits. To estimate direct effects in the construction sector, data from a number of case studies was collected and up-scaled. Then Input-Output methodology, coupled with data on labour intensity, was used to calculate indirect and induced effects. This mixed approach was chosen because direct employment estimates based on the labour intensity for the whole construction sector was deemed too crude to estimate direct effects (i.e., the labour intensity of renovation activities turned out to be, according to the case study-based data collected, substantially higher than the general construction sector labour intensity). Thus, it was concluded that a bottom-up approach using a sub-sector specific employment multiplier for the building renovation industry would ensure a more realistic estimate of direct employment effects. In contrast, the Input-Output method was used as the best method for calculating indirect and induced impacts.

5.2.3 Direct impacts on the construction sector: scaling-up of case studies

In order to produce an approximate estimate of the direct employment effects of a large-scale retrofit of Poland's residential and public sector building stock in the construction sector, a series of data from energy-efficient renovation case studies was gathered. These case studies contained employment, energy and cost data for different types of retrofit projects and included: i) man-months involved in each renovation, divided by skill level (i.e., from architects and professionals, to skilled and unskilled labourers); ii) building types and their respective space heating energy consumption, before and after the renovation; and iii) the total cost of the renovation. **Figure 5-6** shows how case studies are up-scaled when data is available for every type of building and depth of renovation (baseline, deep or suboptimal).

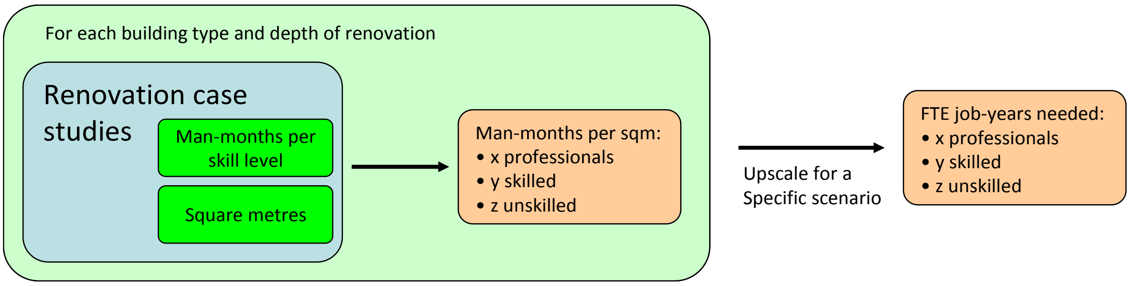

Figure 5-6: Method for *upscaling* case study data to renovation scenarios

However, complete data were not available for all types of buildings and all renovation depths. Thus, some estimates were extrapolated and applied to cases for which data was insufficient or not available. This was accomplished by estimating – for each depth of renovation – labour costs' proportion of total renovation costs and by assuming a *crew composition* of the labour involved (i.e., the respective proportion of labour performed by professionals, skilled, and unskilled workers), following a similar approach as the one employed in Sundquist (2009). These figures were derived from case study data on a selected number of building types for which labour data was available. They were then transferred to building types that lacked labour data (but for which cost data was typically available) by assuming that the proportion of labour costs and the crew composition would be the same for a specific renovation depth, independent of building type. **Figure 5-7** illustrates the transfer method used to estimate man-months per skill level for each building type in each renovation scenario.

Table 5-6 shows the crew composition estimates for the different types of renovation considered. It shows how deep renovations employ more professionals than other types of retrofits. This is because deep energy-efficient retrofits involve more than simple insulation or window replacement activities – they often require consultation with architects and engineers to redesign spaces and systems. These figures also allowed producing estimates of the number of direct jobs disaggregated by skill level and for each renovation type.

Besides, the proportion of labour costs on total costs was assumed to be 25% in all cases for which data was insufficient or not available.

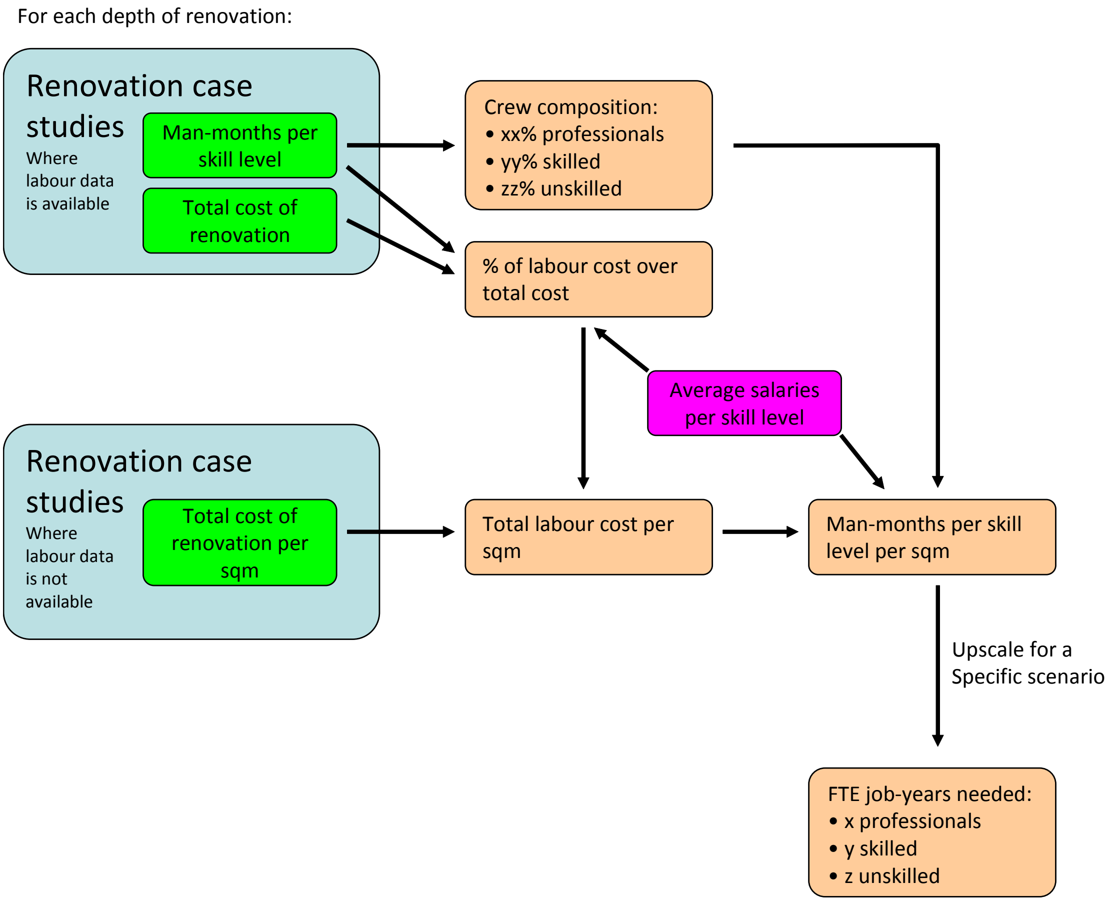

Figure 5-7: Up-scaling method when labour data is not available

	Type of labour	*Crew composition*
S-BASE	Professional	5%
	Skilled	65%
	Unskilled	30%
S-DEEP	Professional	15%
	Skilled	75%
	Unskilled	10%
S-SUB	Professional	10%
	Skilled	75%
	Unskilled	15%

Table 5-6: Crew composition for the different renovation intensities considered

Data sources. The labour data collected in this study came primarily by contacting relevant individuals and organizations, who provided data and estimates for completed projects throughout Europe. There exist no current, completed examples of deep retrofits in Poland. Accordingly, cost and labour data for deep retrofits were primarily derived from Austrian case studies of passive house renovations, and by estimating the corresponding costs of required construction materials in Poland.

Difficulties in data collection. There exists scarce availability of data on the amount and type of labour used in renovation projects of any kind. Data on man-months and the skill levels of renovation project workers are rarely recorded. The levels of energy efficiency improvements obtained often go unrecorded as well. The only data that is typically accessible concerns a retrofit's total cost, and even a rough estimate of the cost split between materials and labour is often difficult to find. Thus, labour data for a number of projects could only be obtained through an intensive, on the ground data collection effort.

The lack of available labor data stems from the heavily-layered structure and specialization inherent in the construction industry. As analyzed by Eccles (1981a; 1981b) and Chiang (2007), the construction industry is typically structured by several layers of contractors, each of which delegates parts of their work to subcontractors. The complexity of rapidly developing construction technologies makes it necessary for subcontractors to specialize in a particular aspect of construction, thereby making it possible for them to remain current in their area of specialization as technology develops. The construction industry's complex structure makes it very difficult for project managers or clients to keep track of the man-hours spent on particular construction projects. An in-depth data collection of the man-hours spent on a given retrofit project would involve contacting all subcontractors and obtaining their estimates on the time spent on each subtask, but architects and project managers are rarely willing to undertake such a time-intensive inquiry.

5.2.4 Direct (negative) impacts on the energy sector: labour intensities

All energy-efficient renovations reduce energy consumption for the building renovated. Therefore a large-scale, national renovation programme involving tens (or hundreds) of thousands of energy-efficient renovations would significantly decrease aggregate energy consumption within Poland's building sector.

1. In this study, direct impacts in the energy sector were estimated by first calculating the reduction in energy demand as follows:

2. For each building type and scenario, energy savings (in kWh per square meter) were estimated. This result was then up-scaled to obtain the total energy savings per building type for each scenario.

3. For each building type, dwellings were classified by energy carrier used as a source of heat (i.e., gas, coal, electricity, district heating or other fuels). A proportion of dwellings was then assigned to each heating type.

4. The annual energy savings, per type of energy carrier for each scenario, was then calculated for the entire building stock.

5. Energy savings from the renovation programs continue to accumulate annually. As previously discussed, the underlying assumption was that renovated dwellings would not change their energy carrier used for space and water heating.

6. Using an energy price forecast for each energy carrier (**Section 5.1.9**), it was possible to estimate the decrease in energy demand for the year under analysis.

The decrease in energy demand was then multiplied by the labour intensity in the energy sector (see "Electricity, gas, steam and hot water supply" in **Table 5-7:**) to obtain the direct reduction in energy sector employment caused by each renovation scenario.

This is a standard method for estimating direct employment impacts caused by a change in sectoral demand. It assumes that variations in demand linearly determine employment effects. This might not be the case in the energy sector, as discussed in more detail in **Section 8.3.1**.

5.2.5 Indirect and induced impacts: Input-Output analysis

Most of the previous works reviewed for this study that aim at estimating the employment impact of a policy intervention rely on Input-Output analysis .

The main purpose of Input-Output tables is to describe the flow of goods and services between industries. Every industry produces goods or services which are then sold to other industries or to final consumers. The basic element of the Input-Output model is the transactions table, the rows of which contain data on the repartition of sales to respective purchasing industries and final consumers. Read by column, the Input-Output table shows how much an industry buys from all other industries. For consistency between different types of goods and services, the table shows the elements in monetary units. Using the transactions table, it is possible to derive the technical coefficient matrix, which shows the amount of input needed by a particular industry from all other industries to create one monetary unit (i.e., 1 USD, 1 EUR or 1 PLN) of product.

The technical coefficient matrix represents the immediate indirect impacts on all sectors of the increase in output of one monetary unit in a specific industry. However, these impacts would have to be recursively re-applied to the same matrix to determine the total indirect impacts of the original increase in output: if 1 PLN of increase in output in Industry A generates 0.25 PLN of output increase in Industry B, then these 0.25 PLN have to be re-injected in the technical coefficient matrix to determine the further indirect impacts generated.

Instead of the complex computations needed to recursively apply these impacts on the technical coefficient matrix, it is possible to calculate a matrix containing the total impacts (direct and indirect) of a one unit increase in output in a particular sector. This is called the Type I Leontief inverse matrix, and can be derived with simple matrix operations from the technical coefficient matrix. This is the matrix used for labour impact analysis. Similarly, it is possible to calculate the Type II Leontief inverse matrix, which treats households as a separate “sector” (for final consumption and labour provided to the rest of the economy), and is therefore used to include in the total impacts the induced effects generated by additional household disposable income. Once the Leontief inverse matrices are known for a particular economy, it is possible to calculate the indirect and induced impacts of the variation in one industry’s demand on the output of each sector of the economy which is included in the matrix.

In order to estimate employment impacts, changes in output are multiplied by the labour productivity in each sector. Labour productivity refers to the number of full-time equivalent (FTE) employees used in a particular sector to produce a certain amount of output.

Following standard Input-Output analysis assumptions, this study assumes that the relationship between labour and output in all industries is linear, that is, if one FTE employee produces 100 units of output, then two FTE employees would produce 200 units of output. For the case of Poland, the Input-Output transaction table is available from GUS, though the latest one available dates from 2005. This transaction table has been used to calculate both the Type I and Type II Leontief inverse matrices subsequently used in this research. The calculation of labour productivities used was a ratio of FTE employees per unit (or millions of units) of output. It was derived from labour intensity data extracted from the database of 2010 GUS (Statistical Yearbook of Industry - Poland 2010) – see **Table 5-7**.

Indirect Impacts and induced impacts from additional income generated by new jobs. As discussed in **Section 5.2.2**, data on a renovation project’s total investment costs are accessible. Thus, an Input-Output approach was used to estimate the positive indirect and induced employment impacts generated by renovation programme investments as follows:

1. Case studies were classified according to the building types used in the building stock model (see **Section 5.1.6**).
2. Renovation costs per square meter were estimated for each building type and retrofit depth.
3. The results were up-scaled for the different scenarios, to obtain the total (annual) investments ofthe renovation programme.
4. Annual investments were then entered into the relevant Input-Output tables to determine the impacts of increased construction industry demand.
5. The result was an increase in output for each economic sector which, multiplied by the labour intensity of the specific sector, quantified the increase in employment generated.

The Input-Output method could similarly be used to estimate the negative (indirect and induced) impacts of the energy savings generated by the programme, by entering the decrease in energy sector demand into the Input-Output tables for indirect and induced impacts.

	FTE per thousands PLN turnover
Agriculture and hunting products	0.0080
Forestry products	0.008
Fishing products	0.0122
Coal and peat	0.0067
Crude oil and natural gas, metal ores, other mining products	0.0041
Food and beverages	0.0033
Tobacco	0.0018
Textiles	0.0083
Wearing apparel, furs	0.015
Leather and leather products	0.011
Wood and products of wood	0.0053
Paper and paper products	0.0026
Printed matter and recorded media	0.0038
Coke, refined petroleum products	0.0004
Chemicals and chemical products	0.0023
Rubber and plastic products	0.0037
Other non-metallic mineral products	0.0044
Basic metals	0.0023
Metal products	0.005
Machinery and equipment	0.0051
Office machinery and computers	0.0028
Electrical machinery and apparatus	0.0041
Radio, television and communication equip.	0.0021
Medical and optical instruments	0.0068
Motor vehicles	0.0017
Other transport equipment	0.0059
Furniture, other manufactured goods	0.0062
Recovered secondary raw materials	0.0032
Electricity, gas, steam and hot water	0.0025
Cold water and its distribution	0.0075
Construction work	0.0023
Sale and repair of vehicles	0.0014
Wholesale and commission trade services	0.0014
Retail trade services	0.0014
Hotel and restaurant services	0.0085
Land and pipeline transport services	0.002
Water and air transport services	0.002
Supporting transport services; tourism services	0.0052
Post and telecommunications services	0.0019
Financial intermediation services	0.002
Insurance services	0.002
Services auxiliary to financial intermed.	0.002
Real estate services	0.002
Renting services of machinery	0.002
Computer and related services	0.002
Research and development services	0.0027
Other business services	0.002
Public administration services	0.0105
Education services	0.0093
Health services	0.0082
Sewage and refuse disposal services	0.002
Membership organization services	0.002
Recreational, cultural and sport. services	0.001
Other services	0.0054
Private households with employed persons	0.0054

Table 5-7: Employees per 1 thousand PLN of turnover in Poland, 2010

Source: Statistical Yearbook of Industry - Poland 2010

Induced impacts from additional income generated by energy savings. As discussed previously, energy efficiency renovations will reduce energy consumption in the buildings renovated and thereby lower energy bills. A portion of the money saved from lower energy bills will be spent; this will increase economic output and create new jobs.

However, the investment required for retrofit programs will itself have a negative impact on household consumption. Therefore, the amount of net disposable income generated by energy savings will depend on how the renovations are financed.

This study assumes that renovations will be financed *interest-free*, and that 80% of the energy savings will be allotted to loan repayment. Thus, 20% of the money saved from reduced energy consumption will be available to households and public building managers for other uses, including increased consumption. This assumption made it possible to calculate the money available for additional consumption each year. This amount was then entered into Input-Output tables to obtain the demand (and jobs) generated in each sector

5.3 Limitations of the Input-Output analysis

As mentioned in Caldes et al. (2009) and in Morriss (2010), the main limitation of Input-Output tables is that the coefficients are constant. Input-Output tables offer a snapshot of the economy (in the case of this study, for the year 2005) that reflect neither changes in the interaction among industries (due, for example, to changes in technology) nor a possible evolution of relative prices among factors of production.

Input-Output transaction tables for an economy are generated only every few years (as mentioned, the latest Input-Output tables available are from 2005). This means that some of the inter-industry coefficients might be outdated, which might be an issue when the study looks at long-term impacts or if the assessed intervention is bound to introduce technological innovations which would themselves change the structure of the transactions table. Some researchers have developed more complex dynamic models to account for technological advance (see Idenburg, 2000). In this regard, more advanced methods based on Computable General Equilibrium analysis allow for analyzing the influence of interventions on the prices of labour, energy, and other inputs, on the structure of the labour market, and on the amount of disposable family income.

A number of other limitations arising from the application of Input-Output methodology in the context of this project are as follows:

- The accuracy of results depends on the quality of information available on the Polish building stock, and on the costs and labour requirements of deep-retrofit interventions. Some of the cost data (mostly on deep retrofits) come from other countries (mainly Western Europe). The parameter of renovation costs is crucial for estimating new jobs created, but it is one of the more uncertain parameters in the combined building stock and employment model used. In order to evaluate the potential impact of this uncertainty on the final results, a sensitivity analysis was conducted for this parameter (see **Section 5.3**).

- While the Polish Input-Output table dates from 2005, GUS' labour productivity statistics from 2010 were used as the most recent available data. Since there are continuous, economy-wide productivity increases (due to experience factors and technological improvements which shift the workload from human labour to machines) necessarily entail significant changes in the rate of labour productivity. This is considered to some extent in the technology/know-how learning factor discussed in **Section 5.1.7**.

- Large fixed costs (i.e., repayment of the investments needed for the construction of power plants and transmission and distribution infrastructure) and variable costs dependent on the amount of fuel consumed (rather than on the amount of labour used) are typical of the energy industry. However, the assumption that employment reductions in the energy sector will be linear, as energy consumption decreases, will likely result in an overestimation of job losses in this sector (for a more detailed discussion of these issues, see **Section 8.3.1**)

- Gains in the efficiency of energy consumption usually result in a lower per-unit price of energy and higher consumption of other goods and services by building users/ Both may offset a portion of the energy savings that would have originally been achieved. The rebound effect is discussed in **Section 8.3.1**. Complex and dynamic effects such as this one will likely impact the final energy savings and net employment generated by the renovation programme. These qualitative issues are analyzed but are not included in the quantitative model because of the constraints posed by the Input-Output methodology.

- The high incidence of informal labour in the construction industry – black and grey labour – will also influence the results of the renovation programme – see **Section 8.6.1** for a discussion on informal labour.

5.4 Sensitivity analysis

The employment impacts of the renovation scenarios analyzed in this study were calculated by using an elaborate, assumption-laden model fed by a multiplicity of data sources, from case study-based data to Input-Output tables. Thus a change in any of the model's assumptions, or the existing uncertainty on some of the data collected for the model, might have a significant impact on the study's results. Therefore, a sensitivity analysis was conducted for the two following parameters: i) the assumed learning factor, i.e., the annual decrease of costs of deep renovations (see **Section 5.1.7**); and ii) the costs of deep renovation at the beginning of the programme (2011). Unlike in the Hungarian study (Ürge-Vorsatz et al., 2010), no sensitivity analysis was done on the evolution of fuel prices and on the proportion of labour costs vs. total renovation costs because in the Polish case the data for those parameters were considered reliable enough.

In the sensitivity analysis performed, a range of different values was used for the two parameters selected, and the consequences of these different values on the final results of the model (i.e., the number of total jobs created) were assessed. The results of this sensitivity analysis are discussed in **Section 7.4**.

5.5 Presentation of results

As in the Hungarian study, most results presented in Chapters 6 and 7 are often provided for two different timeframes:

Results in the year 2020. An analysis of scenario impacts was conducted for the year 2020, by which time the construction industry will have ramped up to the prescribed retrofit rate. 2020 will also be a key year for the implementation of several EU policy strategies (particularly in climate and employment), as discussed in **Section 2.1**.

Results in the medium and long-term. This study also projected the employment impacts in the medium and long-term, through 2080. This made it possible to assess the long-term impacts of the ramp-up period, the learning factor (discussed in **Section 5.1.7**), and of energy savings. However, medium and long-term projections are inherently less accurate, as they cannot take into account technological transformations and significant labour market changes which might occur in the meantime.

In order to make the model's results easier to read, this study often offers combined the impacts generated by the implementation of the programme in both residential and public buildings.

6 Scenario results: Energy and CO_2 savings, investments, cost savings

6.1 Energy savings

All project scenarios result in energy savings, though to substantially different extents. That way, deep retrofits reduce total space heating energy consumption by 84%, while suboptimal retrofits deliver savings of approximately 42% of the aggregated energy consumption in 2011. *Business-as-usual* renovations result in some improvements to a building's energy efficiency according to this study's assumption and *S-BASE* renovations will result in a 25% energy consumption savings. Thus if base or suboptimal renovations were implemented instead of deep retrofits, 60% (for *S-BASE*) and 43% (for *S-SUB*) of Poland's building total energy consumption in 2011 would have been *locked-in* at the end of the implementation period.

The annual energy savings obtained by the retrofit programme increases throughout the years, following an accumulative pattern: buildings renovated in 2012 start to save energy in 2012, but continue to save the same amount of energy in 2013, when additional buildings are renovated and themselves start to save energy. **Figure 6-1** to **Figure 6-5** show the progression of energy use by each Polish building stock category through 2080, for all scenarios. These results only refer to the consumption of the existing stock because new buildings are not included in the calculations.

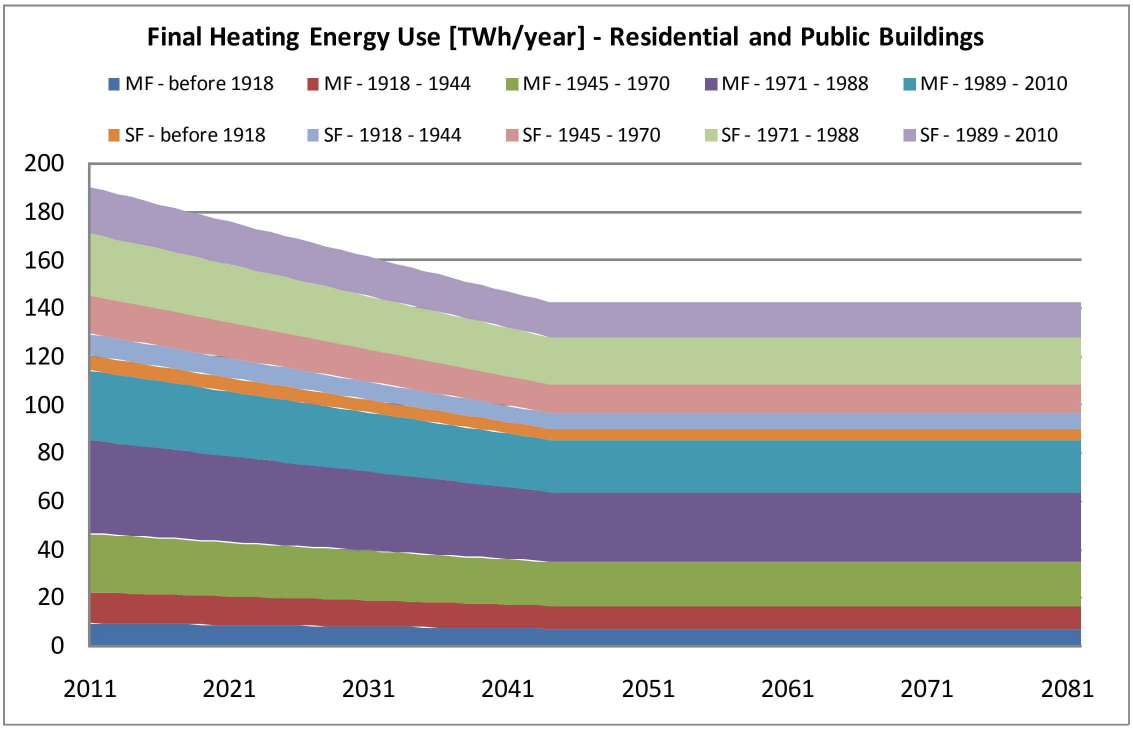

Figure 6-1: Annual space and water heating energy use (TWh/year), by building categories - *S-BASE* scenario

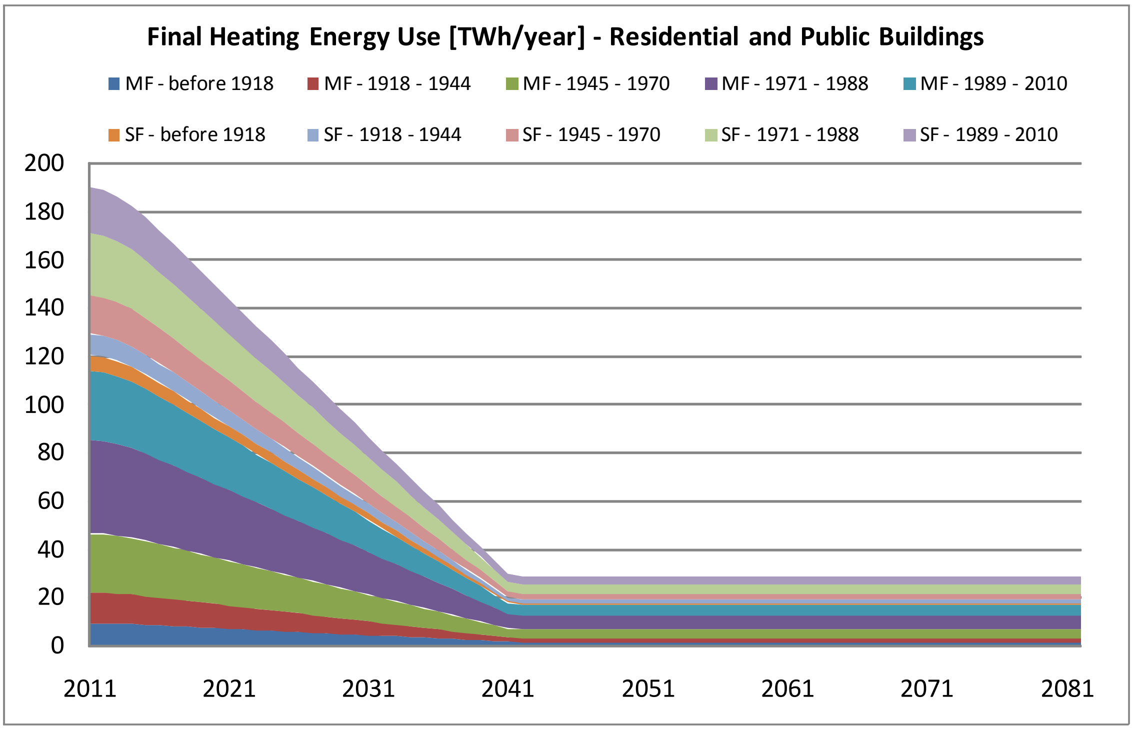

Figure 6-2: Annual space and water heating energy use (TWh/year), by building categories - *S-DEEP3* scenario

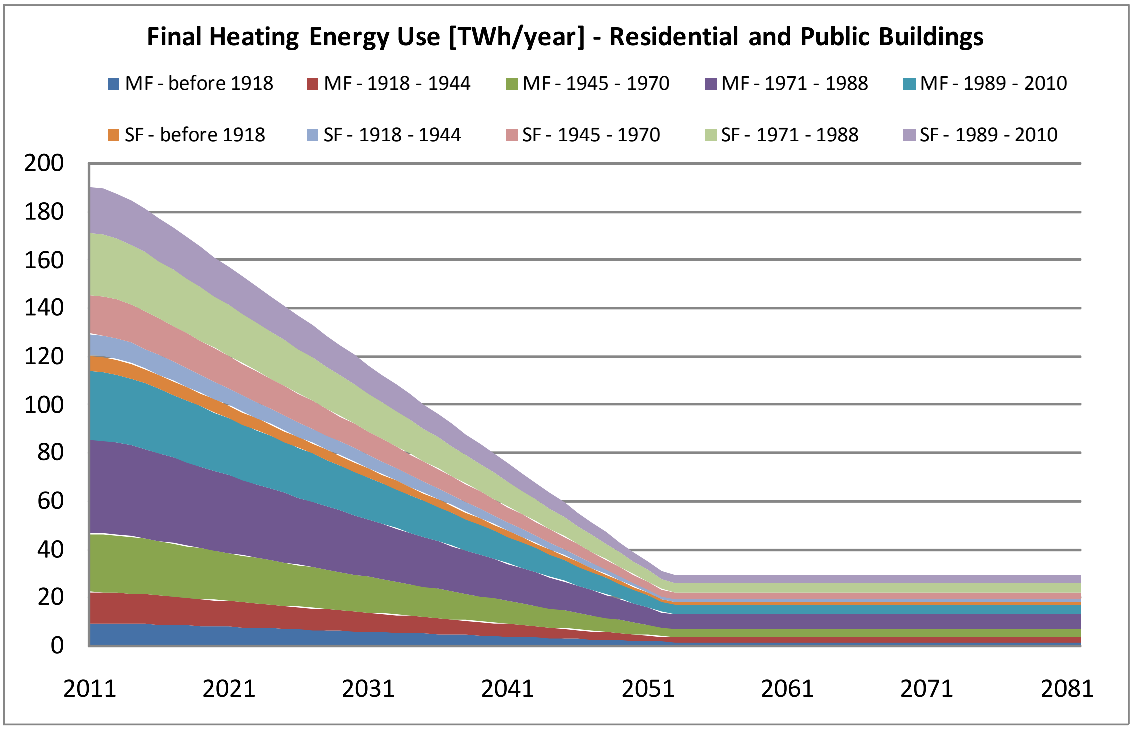

Figure 6-3: Annual space and water heating energy use (TWh/year), by building categories - *S-DEEP2* scenario

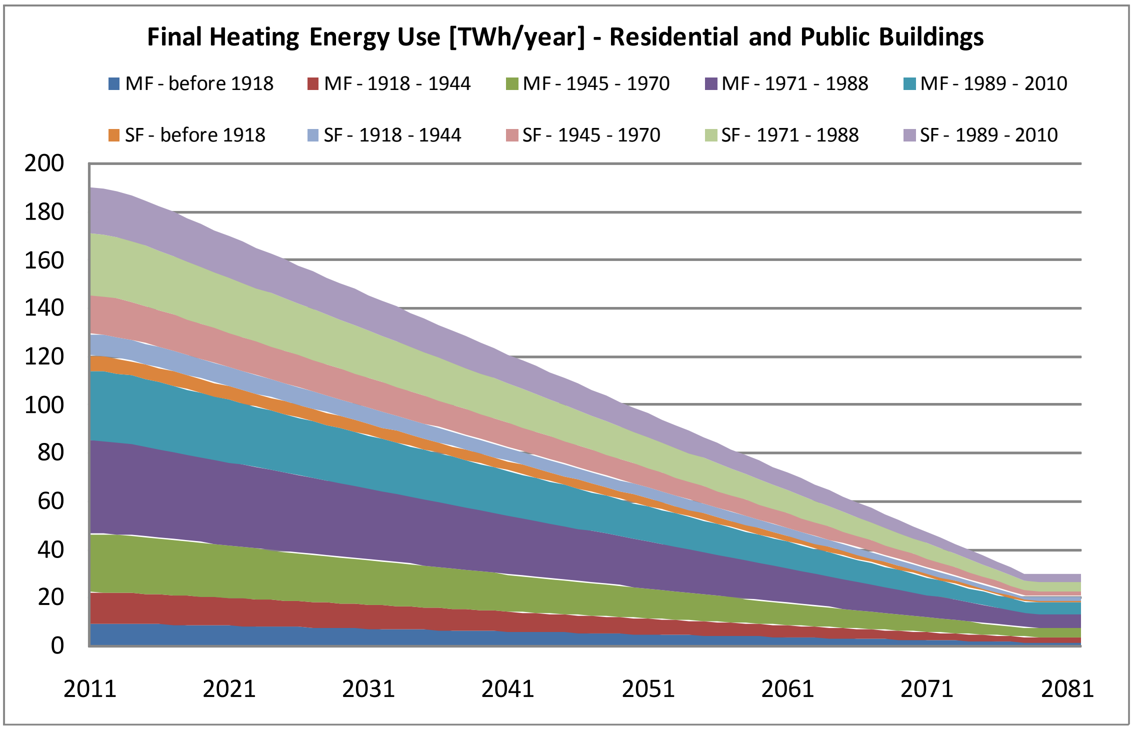

Figure 6-4: Annual space and water heating energy use (TWh/year), by building categories - S-DEEP1 scenario

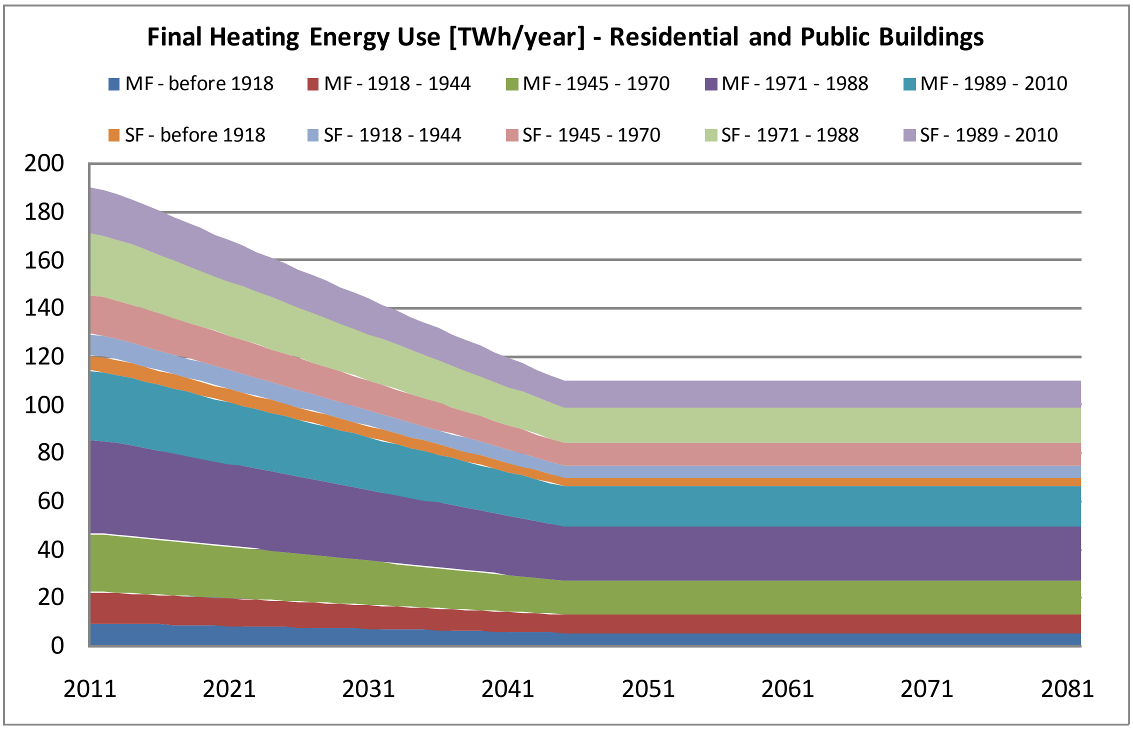

Figure 6-5: Annual space and water heating energy use (TWh/year), by building categories - *S-SUB* scenario

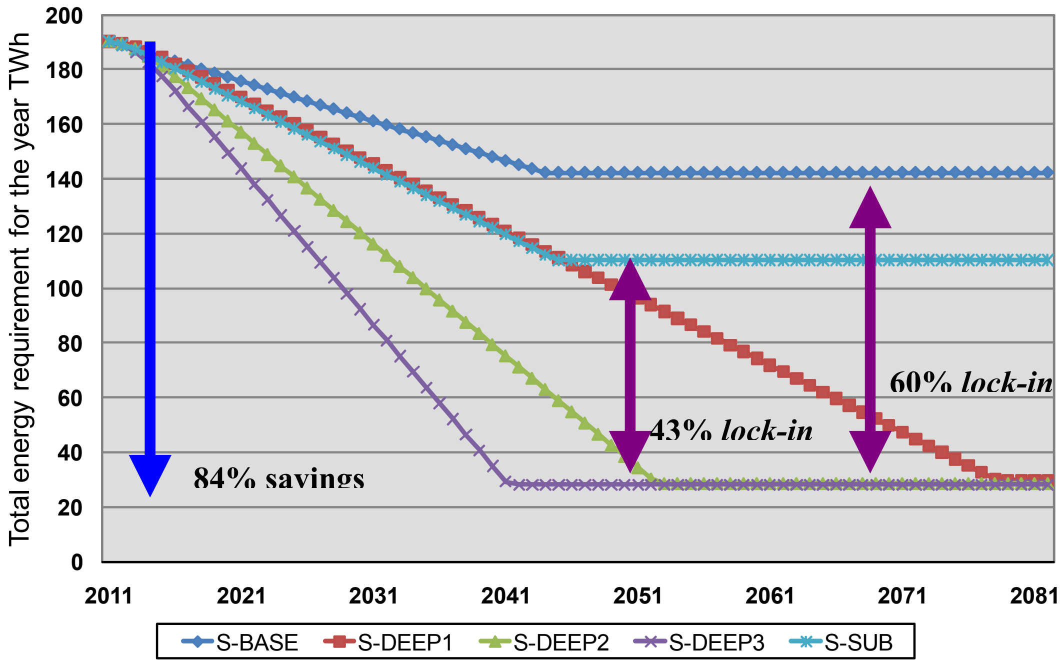

Figure 6-6: Total annual space and water energy requirement (TWh/year) of the existing Polish building stock for all scenarios considered. *Lock-in* figures are expressed as percentages of the total heat consumption in 2011.

6.2 Reduction of natural gas imports

According to data from GUS, the Central Statistics Office (Energy Statistics for the years 2006-2007 and 2008-2009), Poland relied on imports for most (65%) of its natural gas consumption from 2006-2009. Poland's average natural gas production during this period was 195,2 PJ, and its imports – mostly from the Russian Federation – were 361,5 PJ. Thus, to the extent that Poland must rely on natural gas as a component of its energy mix, its dependence on natural gas imports subjects it to potential supply disruptions from natural gas producing countries.

Even though natural gas only supplies 8.2% of the heat consumed by the country's building stock (see **Figure 5-4**), a large fraction of it (69%) is imported. The renovation programmes analysed would therefore allow Poland to significantly reduce its natural gas imports and thereby improve its energy security. **Figure 6-7** illustrates the amount of natural gas that would be consumed by Polish buildings in 2030 under each renovation scenario, including both the natural gas used for end-use heating and consumed by district heating plants. By 2030, natural gas savings would range from 21% (*S-BASE*) to 77% (*S-DEEP3*) of the average buildings-related natural gas imports of the 2006-2009 period. This improvement with respect to natural gas dependency would be also enhanced should recent concessions granted for the exploration of shale gas eventually result in substantial shale gas production in the middle-term.

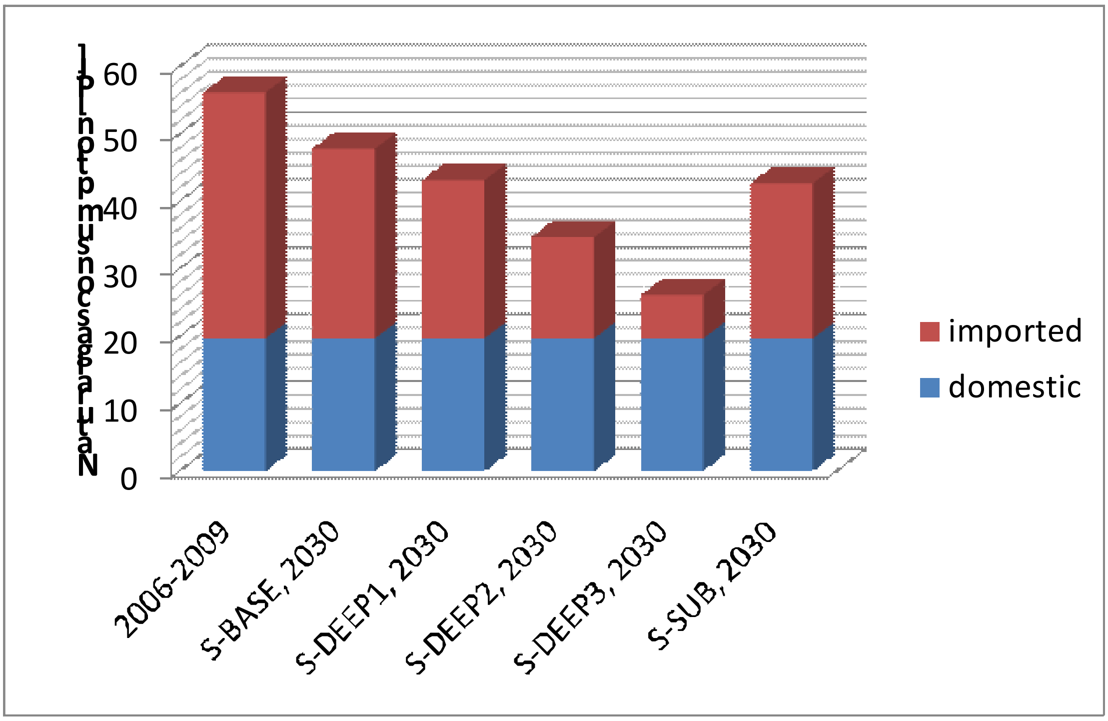

Figure 6-7: Natural gas saved in the year 2030 by retrofit scenarios

6.3 CO_2 emission reductions

The amount of avoided CO_2 emissions in each scenario depends on the energy savings and on the CO_2 emission factors of the energy carriers used for space heating. **Figure 6-8** to **Figure 6-12** illustrate the reduction in CO_2 emissions from the entire Polish building sector through 2080 in the different scenarios and by building types. **Figure 6-13** depicts a summary view of the total decrease in CO_2 emissions for each scenario, which follow, as expected, the same trend as energy savings. It also indicates the extent of CO_2 emissions *locked-in* by the implementation of a suboptimal or base (i.e. Thermo-modernization) renovation programme.

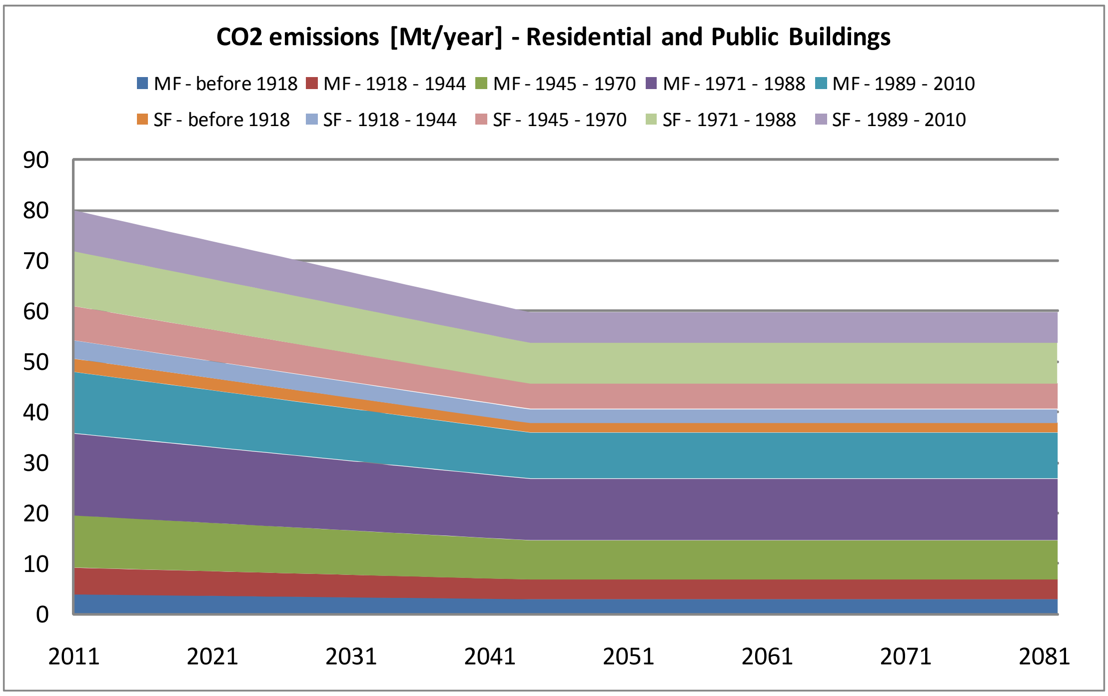

Figure 6-8: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-BASE* scenario

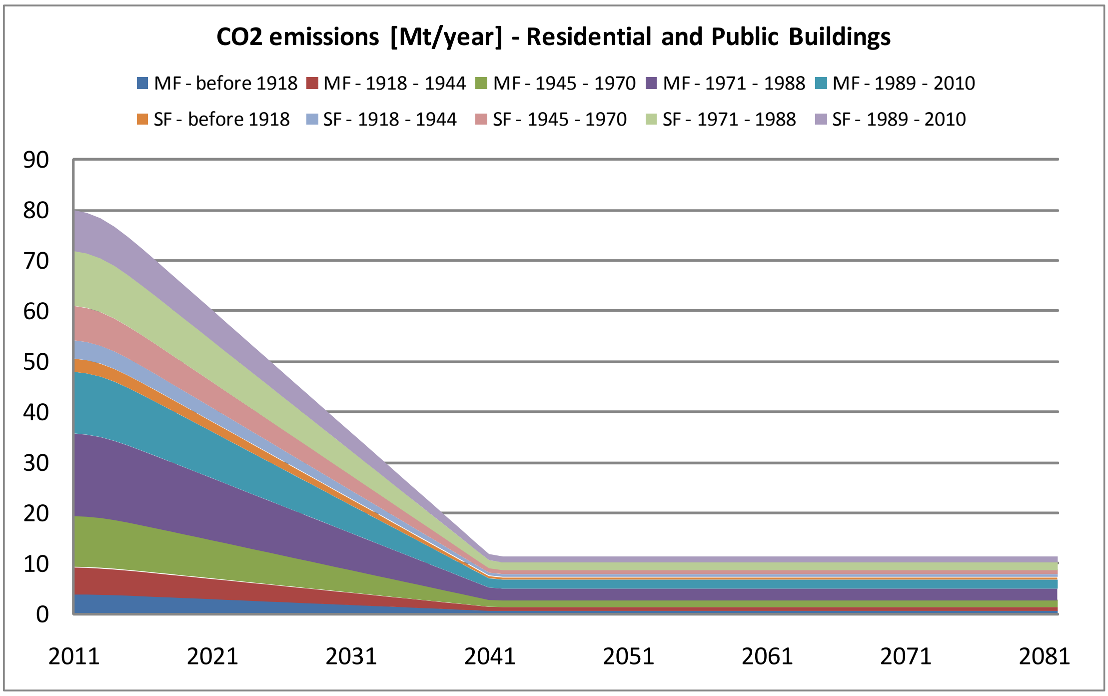

Figure 6-9: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - S-DEEP3 scenario

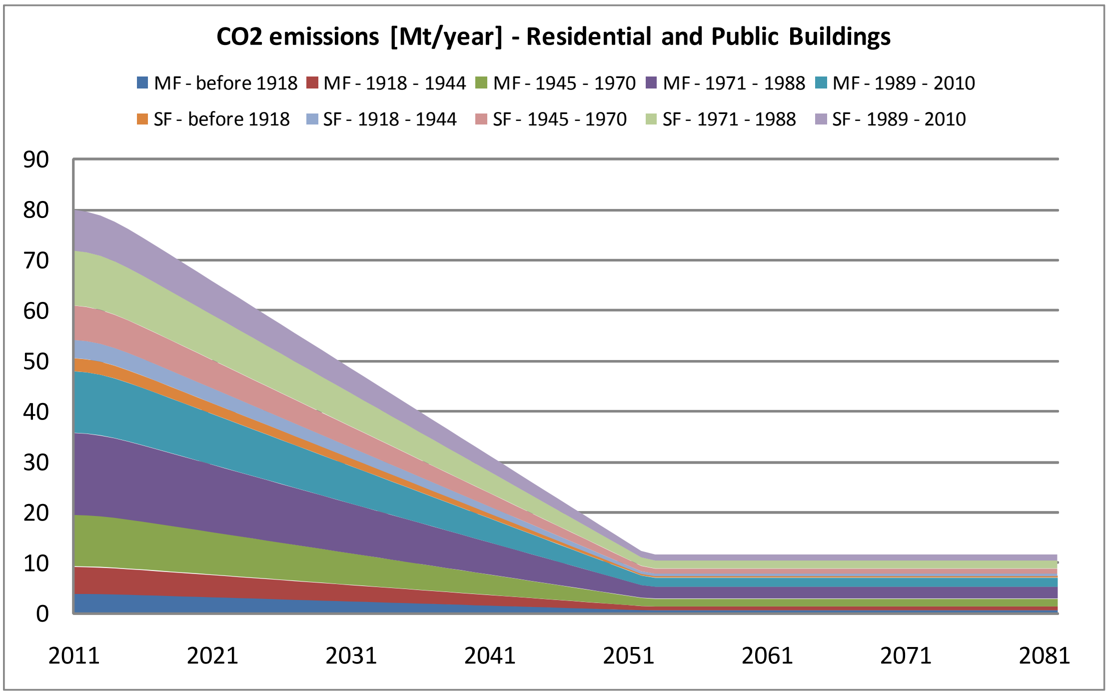

Figure 6-10: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - S-DEEP2 scenario

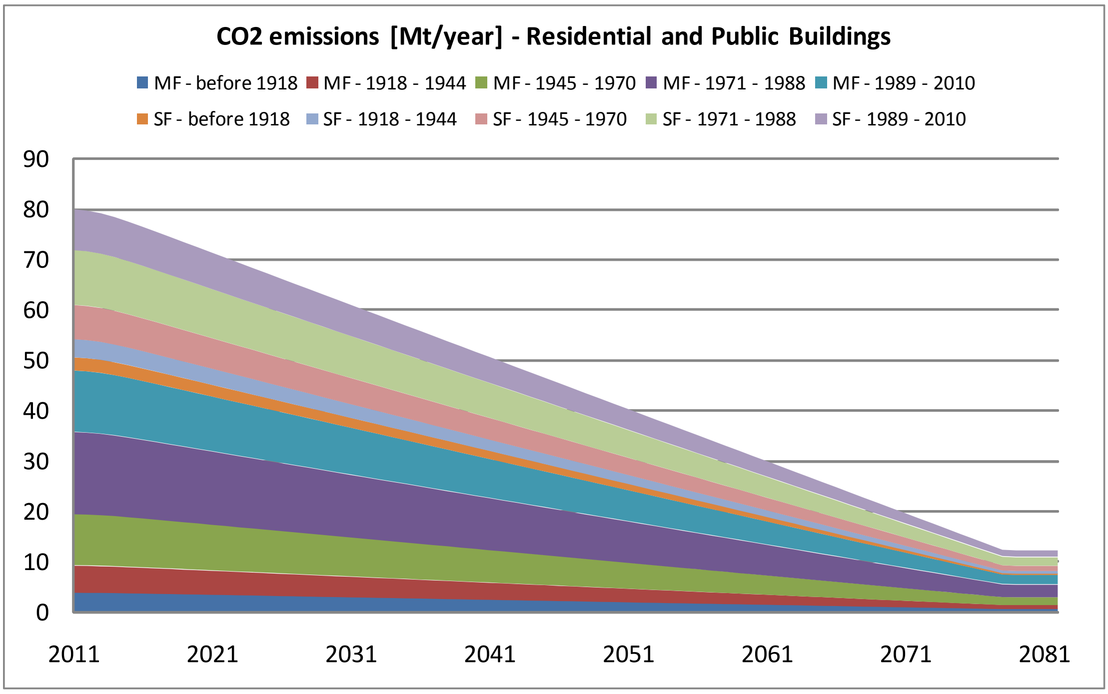

Figure 6-11: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-DEEP1* scenario

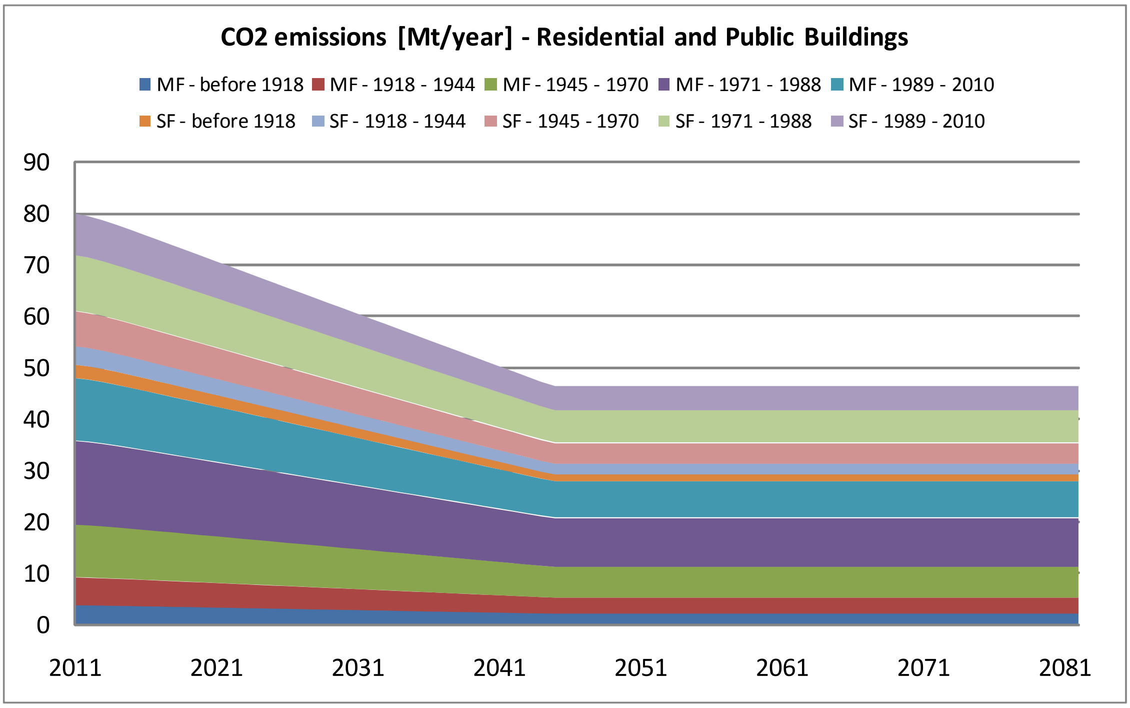

Figure 6-12: Annual CO_2 emissions (Mt/year) for space and water heating, by building categories - *S-SUB* scenario

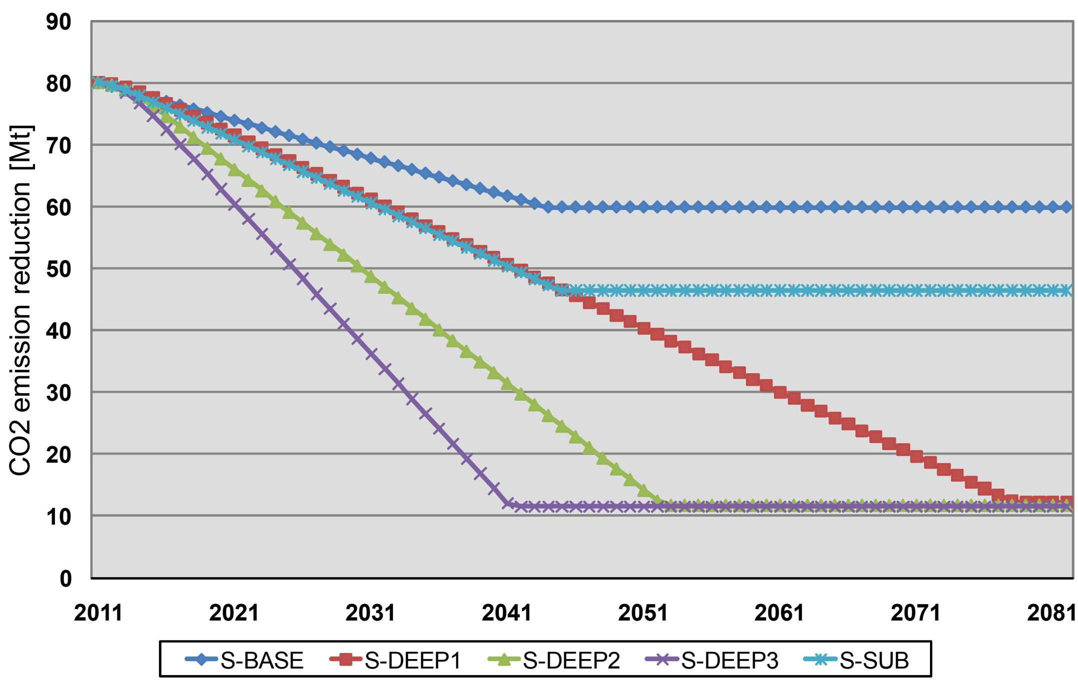

Figure 6-13: Total annual CO_2 emissions (Mt/year) for space and water heating of the Polish building stock, for all scenarios considered

6.4 *Investment needs*

The total investments required to complete the renovations for each type of retrofit were calculated, as reported in this Section. The values were then used both to make a bottom-up estimate of the labour needed and (see **Section 5.2.2**). The total investment required was then used as input data for the Input-Output analysis to obtain the changes in demand for the various economic sectors and, ultimately, the indirect and induced impacts on employment.

The investment costs per square meter in the *S-BASE* scenario are estimates for a *standard* renovation stemming from personal communication and interviews with experts and contractors. For all other scenarios (*S-DEEP1*, *S-DEEP2*, *S-DEEP3* and *S-SUB*), the estimates were based on case-study data from Poland and abroad. These case studies demonstrated successful examples of deep (savings above 75%) and suboptimal (savings around 50%) energy-efficient renovations. The values obtained for deep retrofits were then compared with total cost estimates, which were themselves calculated by aggregating labour costs and the costs of all technical renovation programme components.

It is important to note here that most of the information gathered (from case studies and conversation with experts and industry players) was related to the residential sector. However, since the public sector buildings have been classified in similar categories as the residential buildings, the estimates were transferred across the categories from residential to public buildings. Some data on public sector buildings was also available and used for the model.

All monetary values used were in 2010 Euros. The use of real prices allows avoiding the inflation effects that accompany nominal prices.

6.4.1 Baseline renovation costs (*S-BASE*)

Table 6-1 summarizes the cost estimates for the *S-BASE* scenario. The number of buildings to be renovated per year was assumed to be 2.4% (3% of the non-renovated building stock in 2010) of the total Polish building stock. The consequent floor area comes from the building stock model described in **Section 5.1.6**. Since no learning factor for baseline renovations is assumed, constant annual per floor area unit investment costs for the *S-BASE* scenario are reported.

6.4.2 Deep renovation case studies (*S-DEEP*)

Even though the number of energy-efficient buildings are under construction worldwide – a 2008 study estimates the number of Passivhaus buildings in Europe at 15,000 (Rosenthal, 2008) – the number of renovation case studies containing the information required for this study is minimal. In particular, there exist no completed deep retrofit projects in Poland.

The flagship project for deep energy-efficient renovation in Central and Eastern Europe is SOLANOVA, a 2005 retrofit of a panel building located in Dunaújváros, Hungary, which reduced the building's annual space heating consumption from 220 kWh/m2/year to around 40 kWh/m2/year at a cost of 250 Euros per square meter (Hermelink, 2006).

			Dwellings renovated per year (thousands)	Floor Area renovated per year (millions m^2)	Investment cost (EUR2010/m^2)
Residential	Before 1918 - historic buildings	SF	10.0	0.9	60
		MF	15.1	0.8	38
	1918 – 1944	SF	14.0	1.3	55
		MF	21.0	1.0	40
	1945 – 1970	SF	26.3	2.5	45
		MF	39.4	2.0	45
	1971 – 1988	SF	42.0	4.0	55
		MF	63.1	3.2	36
	1989-2010	SF	31.3	3.0	45
		MF	47.1	2.4	35
Public	Before 1918 - historic buildings	SF	0.0	0.0	60
		MF	0.1	0.3	38
	1918 – 1944	SF	0.1	0.0	55
		MF	0.1	0.4	40
	1945 – 1970	SF	0.1	0.1	45
		MF	0.2	0.8	45
	1971 – 1988	SF	0.2	0.1	55
		MF	0.3	1.2	36
	1989-2010	SF	0.1	0.1	45
		MF	0.2	0.9	35
	TOTAL		**310.7**	**24.9**	-

Table 6-1: Key characteristics of baseline renovations (*S-BASE* scenario).

All of the deep renovation case studies considered in this study are from outside Poland. They achieved at least 80% savings in space heating energy consumption, at a cost range from 452 (multi-family home in Germany) to 2,000 Euros (single family home in Austria) per square meter.

Use of Best Practices. All renovations are distinct: the starting point at which a particular renovation is undergone and the goals of the renovation itself highly vary. Moreover, building owner decisions may be partly based on aesthetic considerations.

In order to estimate the costs per square meter under each scenario, "best practices" – such as Hungary's SOLANOVA project – were used that allow dealing with the diversity of renovation cases that was found amog case studies. The implicit assumption is that a deep retrofit programme would choose the best available option (in terms of the energy savings achieved and its investment costs) for its large-scale replication. Besides, renovation costs from case studies in other countries were adjusted to reflect the labour and materials costs in Poland.

Table 6-2 summarizes the cost estimates and area of floor area renovated per year for the respective deep renovation scenarios analyzed. The cost estimates per square meter reported there section are valid only for the first year of the renovation programme, when the learning factor has not yet started reducing the implementation costs of deep retrofits.

			Dwellings renovated per year (thousands)			Floor Area renovated per year (millions m^2)			Investment cost (EUR2010/m^2) in 2010
			S-DEEP1	*S-DEEP2*	*S-DEEP3*	*S-DEEP1*	*S-DEEP2*	*S-DEEP3*	*S-DEEP*
Residential	Before 1918 - historic buildings	SF	6.3	10.4	14.6	0.6	1.0	1.4	313
		MF	9.4	0.8	22.0	0.5	0.8	1.1	384
	1918 – 1944	SF	8.7	1.3	20.4	0.8	1.4	1.9	356
		MF	13.1	1.0	30.6	0.7	1.1	1.5	457
	1945 – 1970	SF	16.4	2.5	38.3	1.6	2.6	3.6	293
		MF	24.7	2.0	57.5	1.2	2.1	2.9	221
	1971 – 1988	SF	26.3	4.0	61.3	2.5	4.1	5.8	450
		MF	39.4	3.2	92.0	2.0	3.3	4.6	340
	1989-2010	SF	19.6	3.0	45.7	1.9	3.1	4.3	305
		MF	29.4	2.4	68.7	1.5	2.5	3.4	231
Public	Before 1918 - historic buildings	SF	0.0	0.0	0.1	0.0	0.0	0.0	313
		MF	0.0	0.3	0.1	0.2	0.3	0.4	384
	1918 – 1944	SF	0.0	0.0	0.1	0.0	0.0	0.0	356
		MF	0.1	0.4	0.1	0.3	0.4	0.6	457
	1945 – 1970	SF	0.1	0.1	0.2	0.0	0.1	0.1	293
		MF	0.1	0.8	0.3	0.5	0.8	1.1	221
	1971 – 1988	SF	0.1	0.1	0.3	0.1	0.1	0.1	450
		MF	0.2	1.2	0.4	0.8	1.3	1.8	340
	1989-2010	SF	0.1	0.1	0.2	0.0	0.1	0.1	305
		MF	0.1	0.9	0.3	0.6	1.0	1.4	231
	TOTAL		**194.2**	**34.4**	**453.0**	**15.6**	**26.0**	**36.4**	-

Table 6-2: Key characteristics of deep renovations (*S-DEEP* scenarios).

6.4.3 Suboptimal renovation case studies (*S-SUB*)

Unlike with deep retrofits, there is a wealth of case studies in Poland of suboptimal energy-efficient renovations, including those involving retrofits of industrial technology buildings. Table 6-3 **Table 6-3: Key characteristics of suboptimal renovations (S-SUB scenario)**

provides the estimated per unit investment costs for the *S-SUB* scenario. As with the *S-BASE* scenario, annual investments are included because of the study's assumption that there is no learning factor for suboptimal renovations.

			Dwellings renovated per year (thousands)	Floor Area renovated per year (millions m^2)	Investment cost (EUR2010/m^2)
Residential	Before 1918 - historic buildings	SF	10.0	0.9	80
		MF	15.1	0.8	68
	1918 – 1944	SF	14.0	1.3	91
		MF	21.0	1.0	81
	1945 – 1970	SF	26.3	2.5	75
		MF	39.4	2.0	67
	1971 – 1988	SF	42.0	4.0	115
		MF	63.1	3.2	103
	1989-2010	SF	31.3	3.0	78
		MF	47.1	2.4	70
Public	Before 1918 - historic buildings	SF	0.0	0.0	80
		MF	0.1	0.3	68
	1918 – 1944	SF	0.1	0.0	91
		MF	0.1	0.4	81
	1945 – 1970	SF	0.1	0.1	75
		MF	0.2	0.8	67
	1971 – 1988	SF	0.2	0.1	115
		MF	0.3	1.2	103
	1989-2010	SF	0.1	0.1	78
		MF	0.2	0.9	70
	TOTAL		**310.7**	**24.9**	-

Table 6-3: Key characteristics of suboptimal renovations (*S-SUB* scenario)

6.4.4 Total investment costs

Total annual investment costs were estimated throughout the different scenario implementation periods. This way, **Table 6-4** shows the amount of investments needed for each scenario in 2020, while **Figure 6-14** summarizes the annual investments required under each scenario through the end of the programme. Both incorporate the decrease in annual investment costs of deep retrofits that results of the learning factor.

These investments are significant. For the deep scenario, they range between 8.4 and 3.9 billion EUR2010 per year (*S-DEEP3*) and 3.6 to 1.3 EUR2010 per year (*S-DEEP1*), whereas *business-as-*

usual and suboptimal retrofits would require according to the model a constant investment of 1 and 2 billion EUR2010 respectively. For comparison, figures obtained from the Polish Ministry of Finance indicate that the national budget expenditures in 2009 totaled approximately 75 billion EUR. *S-DEEP3* scenario's investment costs would then approach 10% of the national budget (5% for *S-DEEP1*, 8% for *S-DEEP2*, and 3% for *S-SUB*). Of course, substantial energy saving (see below) and other social benefits such as net employment creation, reduced non-GHG emissions, alleviated fuel poverty, etc. would be equally accrued.

	S-DEEP3	*S-DEEP2*	*S-DEEP1*	*S-SUB*
Annual investment costs in 2020, in million Euros 2010 (with learning factor)	6,995	4,997	2,999	2,154

Table 6-4: Annual investment costs by 2020

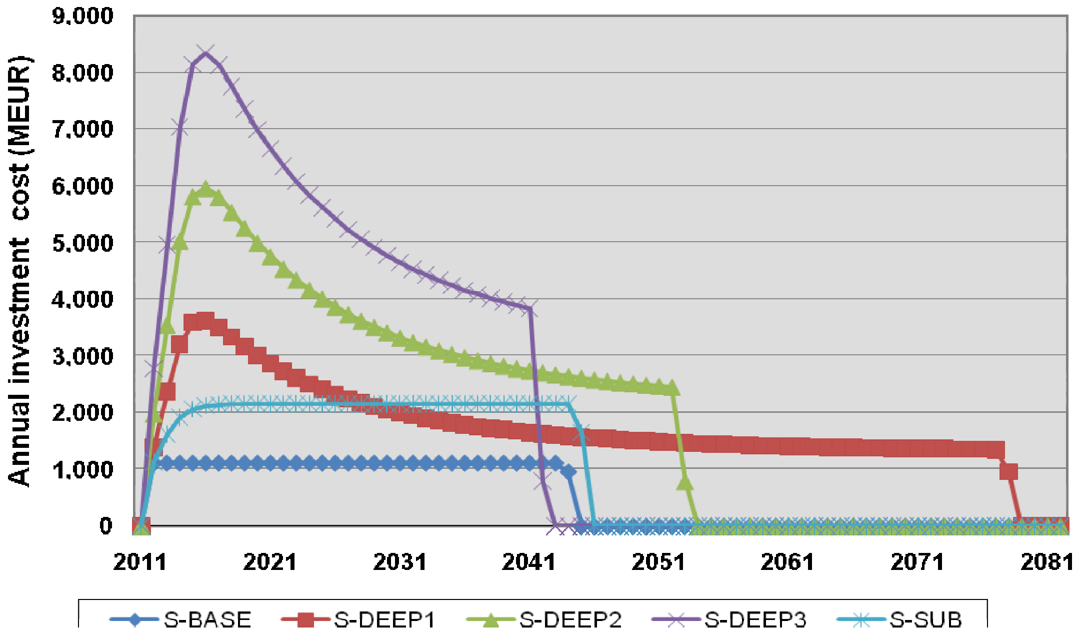

Figure 6-14: Annual investment costs for the renovation scenarios until the end of the programme

6.5 Energy saving benefits and net economic results

To estimate the total energy cost savings from retrofits, energy savings (in MWh) have been multiplied by the per unit forecasted prices of the five different energy carriers – coal, district heating, natural gas, oil and other fuels – used by Polish households for space heating (**Section 5.1.8).** The results for 2020 are shown in **Table 6-5** illustrating the energy cost savings obtained in that year by all buildings retrofitted by the programme to that point. The amount of this energy cost savings compare to the investments listed in **Table 6-4**; the two figures represent the total undiscounted monetary costs incurred and benefits accrued by Polish society in the year 2020.

	S-DEEP3	*S-DEEP2*	*S-DEEP1*	*S-SUB*
Annual energy savingbenefits in 2020, in million Euros 2010	1,305	932	567	643

Table 6-5: Annual energy saving benefits by 2020

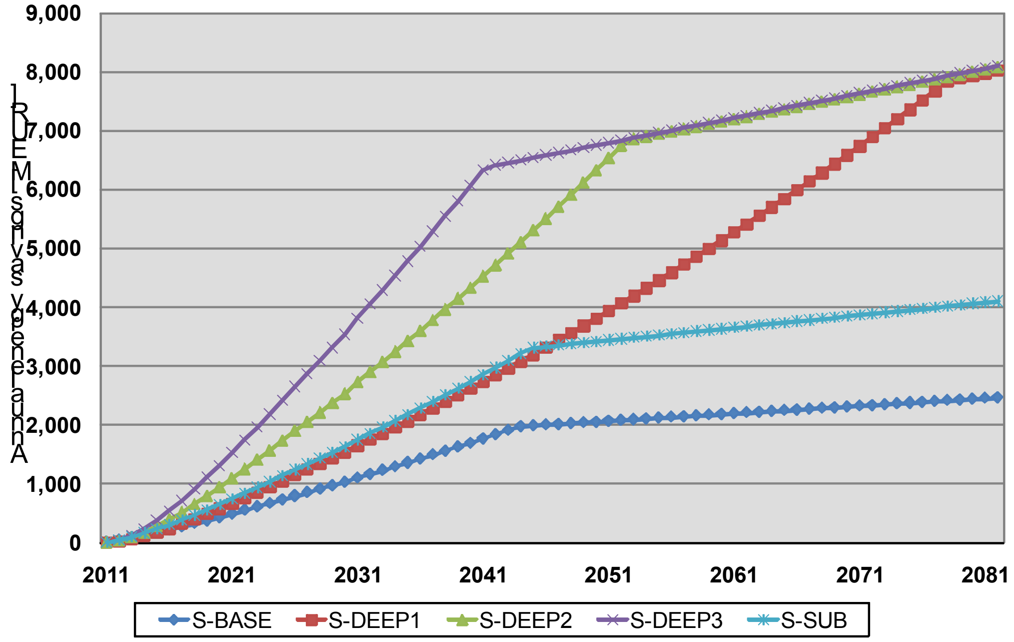

Figure 6-15: Evolution of energy saving benefits generated each year by all scenarios

Figure 6-15 summarizes, for all scenarios through 2080, the energy expenditure savings generated each year by all the retrofits already implemented up to the given year. For each scenario, this cumulative savings compares to the annual investments needed for the renovation programme. **Figure 6-16** to **Figure 6-19** show this comparison separately for all scenarios but *S-BASE*.

As the figures illustrate, annual total national investment needs for the renovation programmes initially exceed annual cost savings from reduced energy consumption; however, energy cost savings progressively increase (as the savings from the buildings retrofitted in the current year are added to the savings from previously renovated buildings). By the year 2035, energy cost savings far outstrip investment costs, especially under deep renovation scenarios.

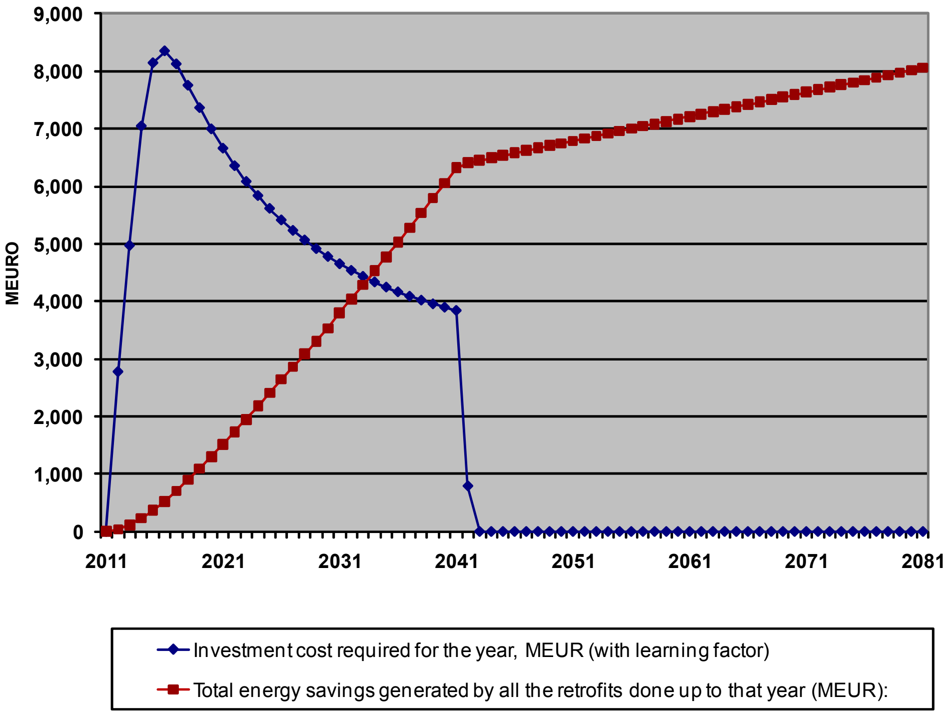

Figure 6-16: Compared retrofit investments and energy cost savings (*S-DEEP3* scenario)

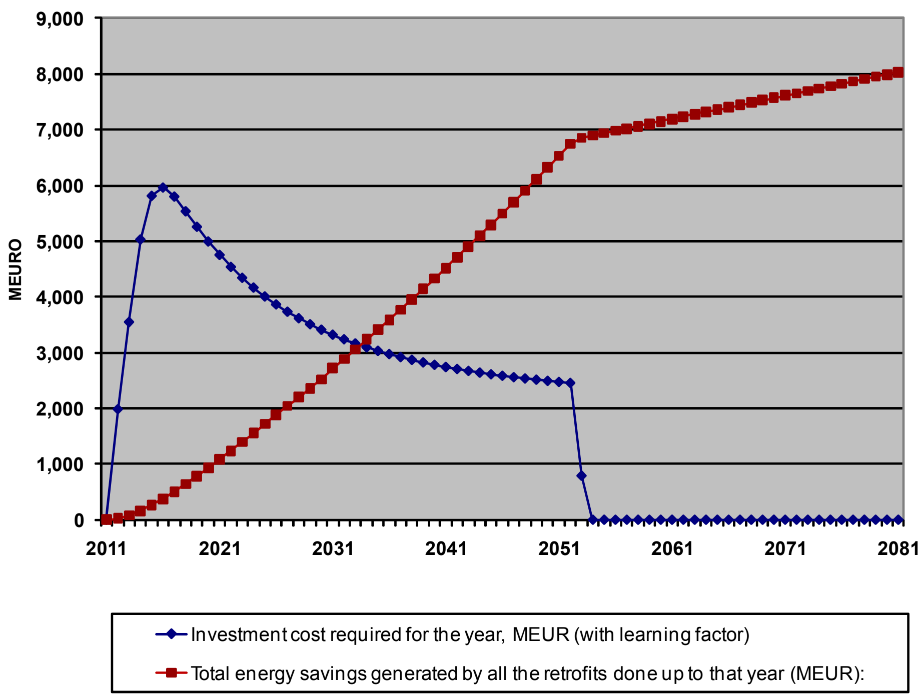

Figure 6-17: Compared retrofit investments and energy cost savings (*S-DEEP2* scenario)

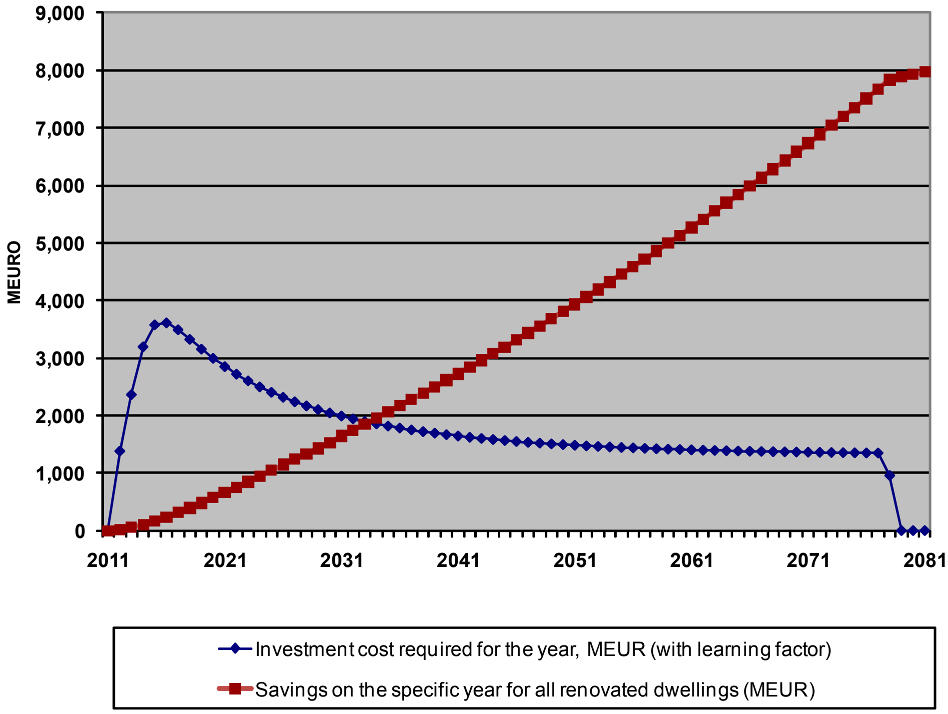

Figure 6-18: Compared retrofit investments and energy cost savings (*S-DEEP1* scenario)

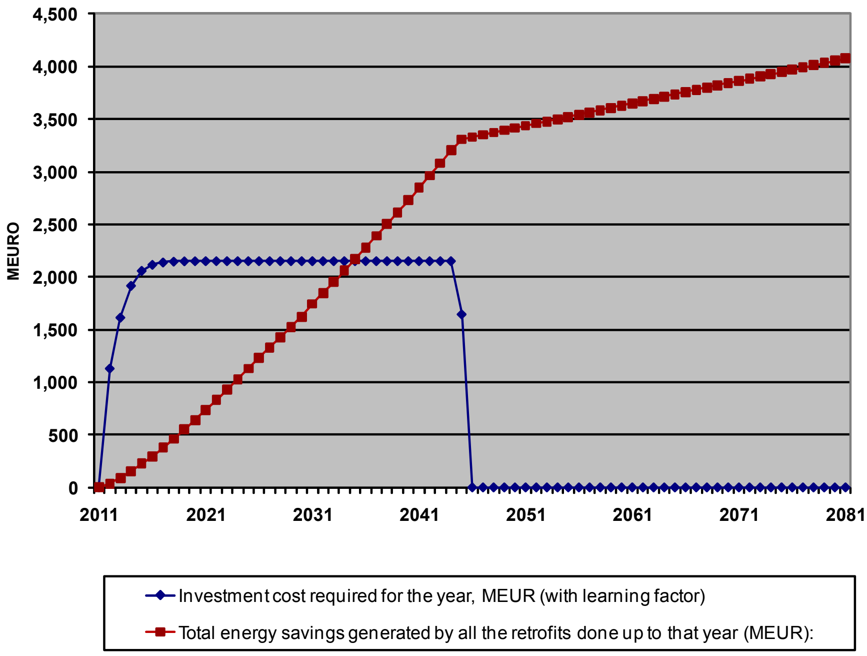

Figure 6-19: Compared retrofit investments and energy cost savings (*S-SUB* scenario)

Finally, total cumulative investment needs were calculated by adding all annual programme investments, and then compared to the total cumulative energy cost savings. **Table 6-6** summarizes these results (undiscounted) for the years 2025, 2050 and 2080, the latter being the year in which all scenarios are completed.

Cumulative investments vs. cumulative savings (undiscounted, Billion Euros 2010)		**2025**	**2050**	**2080**
S-DEEP1	Cumulative investment costs	-40	-85	-124
	Cumulative energy saving benefits	7	67	246
	Undiscounted net benefits	**-34**	**-18**	**122**
S-DEEP2	Cumulative investment costs	-66	-140	-146
	Cumulative energy saving benefits	11	111	332
	Undiscounted net benefits	**-55**	**-29**	**186**
S-DEEP3	Cumulative investment costs	-92	-164	-164
	Cumulative energy saving benefits	15	145	367
	Undiscounted net benefits	**-77**	**-19**	**203**
S-SUB	Cumulative investment costs	-28	-71	-71
	Cumulative energy saving benefits	8	69	182
	Undiscounted net benefits	**-21**	**-2**	**111**

Table 6-6: Cumulative investment needs compared with cumulative energy cost savings (undiscounted)

From a total investment cost perspective, a more gradual implementation of a deep renovation programme is preferred. Due to the relative inexperience with deep renovation know-how and technologies, initially these will undoubtedly be more expensive than after a learning period when experience accumulates and more mature markets and competitive supply chains are established. Thus a more aggressive renovation programme (i.e., 450,000 units per year, *S-DEEP3*) will result in higher total costs – 164 billion Euros, which compares to 146 and 124 billion Euros of *S-DEEP1* and *S-DEEP2* scenarios. These costs can be shared by building owners, the government and even utility companies, with additional sources of capital like the sale of CO_2 quota and revenues from EU ETS auctions, helping to meet the financing needs of the program (see financing options in **Section 8.5**). Besides, a careful implementation can minimize total costs, i.e., building types with a lower cost per sqm. (e.g., multi-family units built in 1945-1970) can be retrofitted first and then proceed with more expensive typologies (e.g., single-family units from 1971-1988) at later stages, once the learning factor has effectively reduced the cost of retrofits.

On the benefits' side, a more ambitious implementation rate results in a faster harvesting of energy saving benefits: by 2080, the total accumulated undiscounted net benefits of *S-DEEP3* amount to 203 billion Euros, whereas *S-DEEP2* and *S-DEEP1* generate 186 and 122 billion Euros each. All in all, these results indicate that in the long-term, the energy saving benefits accrued through retrofits surpass investment costs, and that deep retrofits are preferable to suboptimal from an undiscounted private costs vs. benefits perspective. Among deep scenarios, a more ambitious retrofit rate delivers more undiscounted net benefits and is a preferable alternative as long as the potential negative effects described in **Sections 7.3.27.3.3** and **9.2.2** (e.g., destruction of the previously created employment because of the learning factor, bottlenecks in the supply of labour, capital and materials) are dealt with. Because of the existing trade-offs, *S-DEEP2* scenario can be suggested as a rate of retrofit that maximizes net benefits without compromising the feasibility of the programme or creating imbalances in the labour and other markets affected by the retrofits.

A careful of review of these economic results, which are less appealing than the ones obtained for the preceding Hungarian study (Urge-Vorsatz et al., 2010, concluded that that among all the model parameters the main difference has to do the with the fuel mix: most Polish buildings use coal (either directly or as district heating), a cheaper fuel than natural gas, for heating. This is the key factor which makes deep retrofits look relatively less attractive than suboptimal ones in Poland. If Poland had substituted coal as a heat source by natural gas (as Hungary did in the 1990s), net economic benefits would be achieved much earlier (before 2050). This conclusion, obtained as a *by-product* of the comparison of both studies, indicates that a coal-based economy is less likely to adopt energy efficiency measures because it has fewer incentives to do so.

6.6 Comparing with an alternative abatement strategy: the cost of CCS

Among the carbon reduction options available to Poland, carbon capture and storage (CCS) stands out given the country's energy system reliance on coal, which under *business-as usual* conditions is likely to remain a main source of primary energy in the coming decades. This is the direction shown by the current by the energy strategy adopted by the Polish government – *Energy Policy of Poland until 2030* –, which considers coal as a key element for securing Poland's energy security. It also establishes as measures for mitigating the environmental impact of the power sector the following through (Polish Ministry of Economy, 2010, p. 22):

- "Active participation in implementing the initiative of the European Commission to build large-scale demonstration facilities for carbon capture and storage (CCS) technologies ;
- Applying CCS technologies to support crude oil and natural gas extraction;
- Intensifying research and development on the CCS technology and on new technologies which allow using captured CO2 as a raw material by other industry branches;"

Equally, critics to Poland's energy policy argue that maintaining the existing structure of the coal-dependant energy sector in Poland in the context of its national and EU policies will be only possible through the widespread use of CCS (ISD, 2009).

This gives the opportunity to compare the cost of reducing carbon emissions through the proposed energy efficiency interventions in the building sector with the cost of doing the same through CCS. Both options address two different sources of carbon– final heat consumption in buildings and power generation in coal-fired power plants – that greatly contribute to Poland's total CO_2 emissions.

For that, per unit costs of carbon emission reduction through CCS for Poland have been first obtained from the report *Insuring Energy Independence. A CCS Roadmap for Poland* (BEST, 2010). These figures (see **Table 6-7**) include the cost of capturing, transporting and storing CO_2 in various power plant typologies, but not capital costs (thus being a conservative estimate) They also incorporate a learning factor, i.e., the cost CCS decreases along time as the technology becomes more mature. These costs per unit carbon mitigated are in the lower range of those reported by IPCC (2005), which emphasizes the conservative character of the estimates.

	2010-2019	2020-2029	2030 and beyond
Pulverised coal	27.2	19.2	18.2
Oxy-combustion	37.2	21.2	19.2
IGCC	31.2	16.2	15.2
NGCC	54.2	42.2	40.2

Table 6-7: Per unit cost of carbon emission reduction through CCS in Poland (EUR2010/tCO_2)

Source: BEST (2010)

Then the total cost of reducing the same amount of CO_2 emissions as the model scenarios has been estimated for the time horizons 2025, 2050 and 2080. For that, the amount of carbon emissions mitigated under each scenario has been multiplied by the per unit cost of CCS-based mitigation in Poland. More specifically, a lower bound estimate has been produced by applying the cost of CCS in an IGCC power plant (the cheapest technology in the long-term) and a higher bound estimate has been obtained by applying the cost of CCS in a pulverised coal power plant (the most expensive coal-based technology). NGCC was disregarded because CCS is assumed to be prioritised in coal-fired power plants. Finally, these estimates assume that CCS can be implemented immediately[7].

The results are presented in **Figure 6-20** and **Table 6-8**. They indicate that even though reducing carbon emissions through CCS is cheaper in the mid-term, in the long-term retrofitting buildings is a preferable option. This happens because building retrofits deliver net benefits whereas CCS entails costs throughout the whole period: by 2080, the energy efficiency scenarios deliver net positive benefits whereas CCS only reports net costs.

[7] However, according to ISD (2009), it is unfeasible to have an operating CCS capacity before 2015-2016.

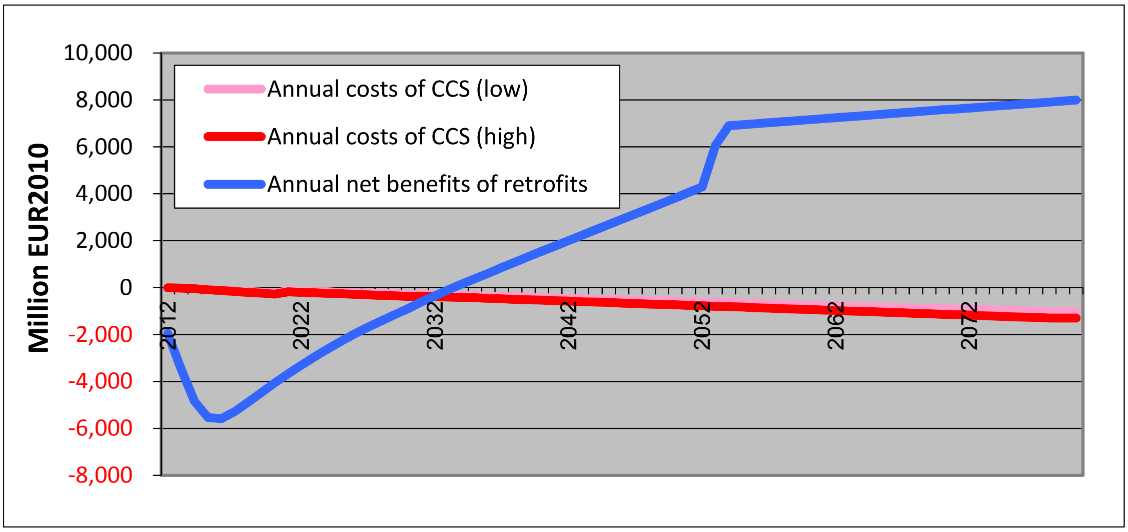

Figure 6-20: Annual costs of capturing through CCS the same amount of CO_2 as the *S-DEEP2* scenario (low- and high-bound estimates) vs. annual net benefits of retrofits in *S-DEEP2*

Alternative CCS mitigation costs (undiscounted, Billion Euros 2010)		2025	2050	2080
S-DEEP1	High-bound (Oxy-combustion plant)	-2	-15	-47
	Low-bound (IGCC plant)	-2	-12	-37
S-DEEP2	High-bound (Oxy-combustion plant)	-4	-25	-64
	Low-bound (IGCC plant)	-3	-20	-51
S-DEEP3	High-bound (Oxy-combustion plant)	-5	-33	-72
	Low-bound (IGCC plant)	-4	-26	-57
S-SUB	High-bound (Oxy-combustion plant)	-3	-16	-35
	Low-bound (IGCC plant)	-2	-13	-27

Table 6-8: Cost of mitigating the same amount of carbon emissions as scenarios through carbon capture and storage (CCS)

It must be also noted that CCS with geological storage – unlike energy efficiency retrofits – increases the production cost of coal-based electricity between 20 to 90% (IPCC, 2005). Besides, though it may have some also have effects on employment and non-GHG emissions, it does not bring as many co-benefits.

6.7 The economic value of external benefits: avoided GHG and non-GHG emissions

The combustion of fossil fuels is responsible for the emission of a large amount of GHG (CO_2) and non-GHG emissions like nitrogen oxides (NO_x), sulphates (SO_x), particulate matter (PM) and non-methane organic volatile compounds (NMVOC). The latter are is particularly relevant in the case of Poland, where 44.5% of the buildings' heat demand is met by coal and 75% of the district heat consumed (which in itself cover 41.9% of the buildings' heat demand) – see **Section 5.1.8** –

is based on coal. As known, coal is an important source of carbon emissions and of the above mentioned non-GHG pollutants.

The extent of such reduction in non-GHG emissions under different scenarios has been estimated and compared to current total emission level of these pollutants in Poland (see results in **Section 8.4.2**). The economic value of these reductions can be economically assessed through their external costs of emission. In the EU, research initiatives such as ExternE and NewExt have developed complex methodologies for the economic valuation of such external costs of emissions including their effects on human health, ecosystems, agriculture and materials.

For the valuation of the external benefit of non-GHG emissions, per unit values of avoided external costs estimated by the NewExt project (Friedrich, 2004 – see **Table 6-9**) have been applied to the amount of avoided emissions reported in **Section 8.4.2**.

Non-GHG pollutant	External cost of emission [EUR2010 t^{-1}]
NO_x	4,037
SO_x	3,460
PM10	30,975
NMVOC	1,287

Table 6-9: Average damage factors (external cost) as estimated by the NewExt project (Friedrich, 2004) for selected non-GHG pollutants.

On the other hand, the economic value of avoided CO_2 emissions has been estimated through the social cost of carbon report by IPCC (2007), i.e., the external cost of CO_2 emissions. In particular, the central value of the social cost of carbon provided by this source ($ 50 per ton of carbon, assumed to be in 2000 monetary units) has been converted to 13.4 EUR2010/tCO_2 and then applied to the CO_2 emission reductions figures shown in **Section 6.3**. These calculations also assume a 3% increase per year in the social cost of carbon as indicated by IPCC (2007).

The total undiscounted value of the external benefit of reducing GHG and non-GHG emissions are presented (by scenarios) in **Table 6-10** and for *S-DEEP1* scenario in **Figure 6-21**. One first conclusion is that cumulative social (external) benefits are larger than the cumulative energy saving benefits presented in **Table 6-6**.

However, the comparison with the cumulative investment costs or energy saving benefits is not straightforward. For that, private and social (non-market) benefits have to be compared in the methodological framework of social cost-benefit analysis. This usually entails correcting labour and material costs and energy prices, and applying a social discount rate (OECD, 2006). A proper comparison requires their assessment in the social cost-benefit analysis framework incorporating additional external benefits (e.g., reduced energy poverty-related excess winter mortality) would likely yield more attractive cost-benefit ratios.

Cumulative external benefit of avoided GHG and non-GHG emissions mitigation (undiscounted, Billion Euros 2010)		2025	2050	2080
S-DEEP1	External benefit of avoided carbon emissions	2	22	137
	External benefit of avoided non-GHG emissions	9	74	189
	Total external benefits (undiscounted)	**10**	**96**	**326**
S-DEEP2	External benefit of avoided carbon emissions	2	37	174
	External benefit of avoided non-GHG emissions	14	122	325
	Total external benefits (undiscounted)	**16**	**158**	**499**
S-DEEP3	External benefit of avoided carbon emissions	3	47	186
	External benefit of avoided non-GHG emissions	19	160	355
	Total external benefits (undiscounted)	**23**	**207**	**541**
S-SUB	External benefit of avoided carbon emissions	2	23	90
	External benefit of avoided non-GHG emissions	9	73	177
	Total external benefits (undiscounted)	**11**	**96**	**267**

Table 6-10: External benefits of avoided CO_2 and non-GHG emissions

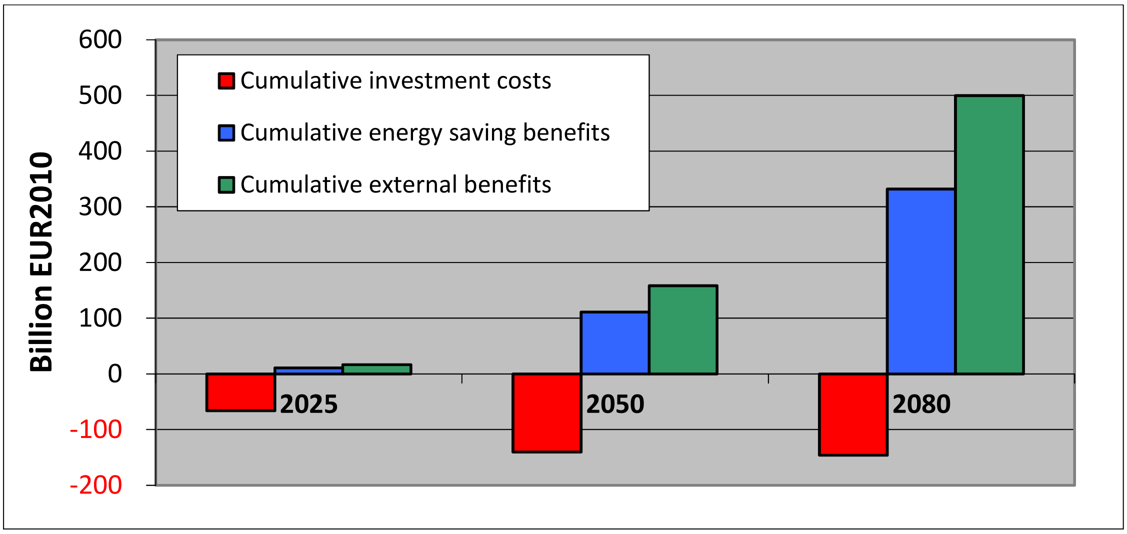

Figure 6-21: Cumulative investment costs vs. cumulative private energy saving benefits and social external benefits (*S-DEEP2* scenario).

A second conclusion is that even though non-GHG pollutants are emitted in significantly lesser quantities than CO_2, the external benefits associated to their reduction is above that of the carbon emission reductions (see **Table 6-10**). A conclusion to be drawn from this comparison is that the effects of non-GHG emissions on present generations (i.e., on human health, ecosystems, agriculture, etc.) can be a policy lever as important as the impacts of climate change on future generations when *dirty* fuels such as coal are in the picture.

7 Estimation of employment effects

7.1 Direct (positive) employment effects in the construction sector

As described in the methodology chapter, the direct impacts of the renovation scenarios on the construction sector have been obtained by up-scaling labour data from case studies. **Table 7-1** and **Figure 7-1** show the direct impacts (in thousand FTE per year) divided by skill level in the year 2020 for all scenarios.

	S-BASE	S-DEEP1	S-DEEP2	S-DEEP3	S-SUB
Million Euros invested in 2020	1,104	2,999	4,997	6,995	2,154
In thousand FTE units					
Professional	1	7	11	16	3
Skilled	12	34	57	80	26
Unskilled	6	5	8	11	5
Direct labour involved: total	19	46	76	106	34
FTE per million EUR invested: professionals	1	2	2	2	2
FTE per million EUR invested: skilled	11	11	11	11	12
FTE per million EUR invested: unskilled	5	2	2	2	2
FTE per million EUR invested: total	17	15	15	15	16

Table 7-1: Direct labour impacts on the construction sector, divided by skill level

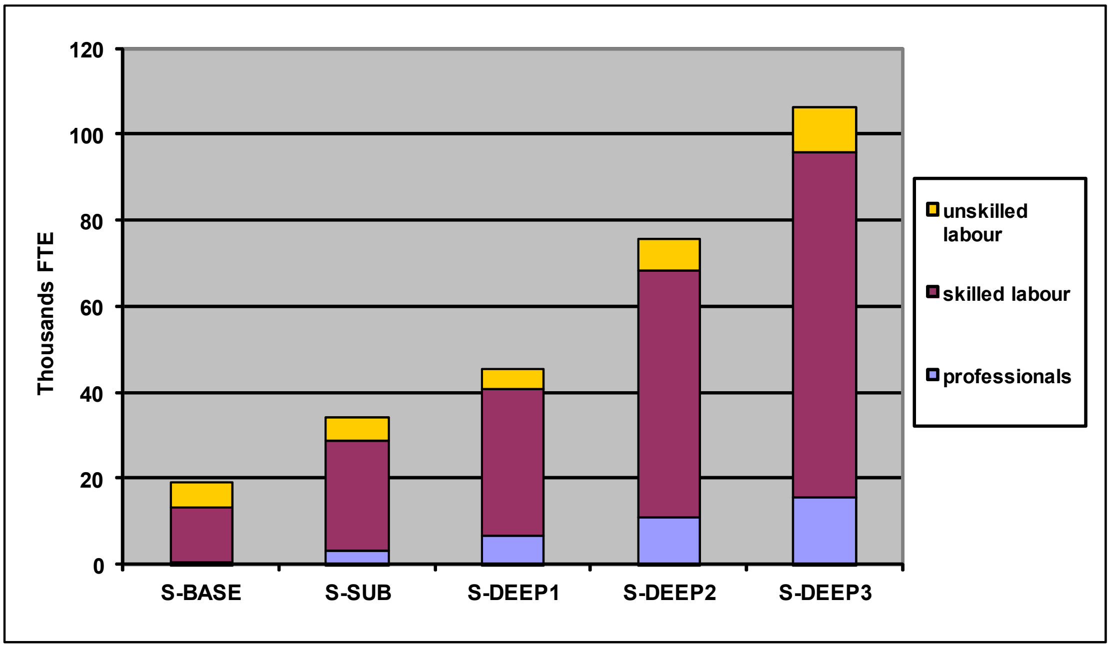

Figure 7-1: Direct employment impacts in construction by skill level in 2020

These results show the difference in direct impacts of the various scenarios proposed, and illustrate some qualitative aspects – such as the qualifications required by the new positions – of the jobs created according to the different scenarios. The labor intensity (i.e., amount of total FTE generated per million Euros invested) of *S-DEEP* scenarios is lower than in suboptimal and base because deep retrofits require a higher proportion of professionals (e.g., architects and engineers) that earn higher wages than skilled and unskilled workers. Therefore the total number of people involved per unit of investment invested is lower. In any case, the results of the bottom-up model used for the estimation of direct impacts indicate that building retrofits create more jobs per unit of investment than the average construction business: the labour intensity for deep renovations – 15 FTE units per million Euro invested – is considerable higher than the labour intensity of the entire construction industry – 9 FTE/MEUR according to GUS (2010). This also shows that the renovation of buildings is characterized by a higher labor-to-capital proportion than other construction activities such as infrastructure construction, which involve much more machinery and technology.

The evolution of direct impacts throughout the programme is shown in **Figure 7-2**, which displays the trend of total direct employment effects for all scenarios until their end. The graph clearly displays the initial ramp-up period of deep and suboptimal scenarios, where a fast uptake (and possibly training) of new workers takes place, followed by a gradual decrease in total direct employment caused by the learning factor (less workers are needed to complete the same amount of work as experience accumulates and economies of scale develop). This reduction is an element to be considered when analysing the durability of the additional jobs created in the construction industry by the renovation programme.

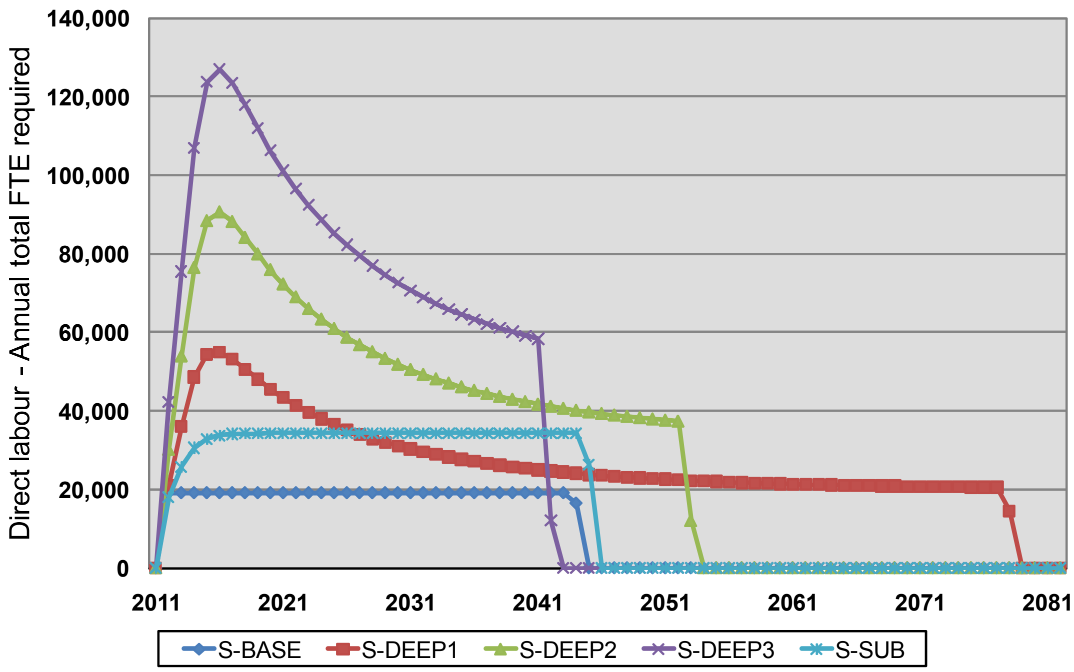

Figure 7-2: Evolution of direct employment impacts on the construction sector

Additionally, **Figure 7-3** to **Figure 7-6** below have been produced in order to have a more detailed visual of the results by skill level. They describe for S-SUB and S-DEEP scenarios the proportion of professionals needed, as well as skilled and unskilled workers. As previously noted, deep renovation scenarios have a higher proportion of professional figures involved due to the knowledge and expertise needed for the substantial changes in the building required for the achieving the expected large reduction in its energy consumption.

Figure 7-3: Direct employment impacts divided by skill level - *S-DEEP1* scenario

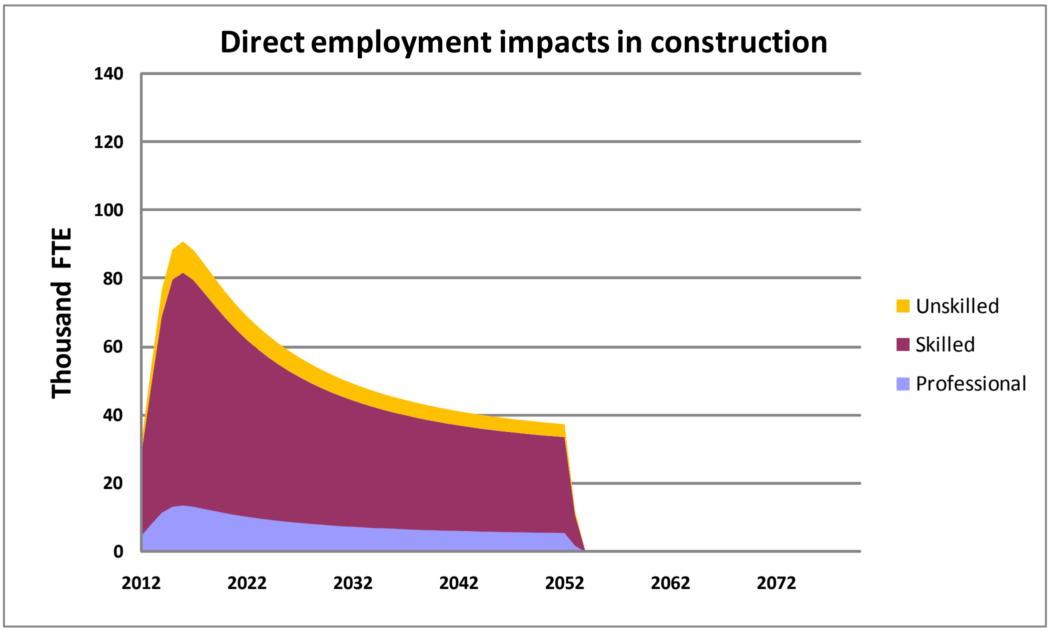

Figure 7-4: Direct employment impacts divided by skill level - *S-DEEP2* scenario

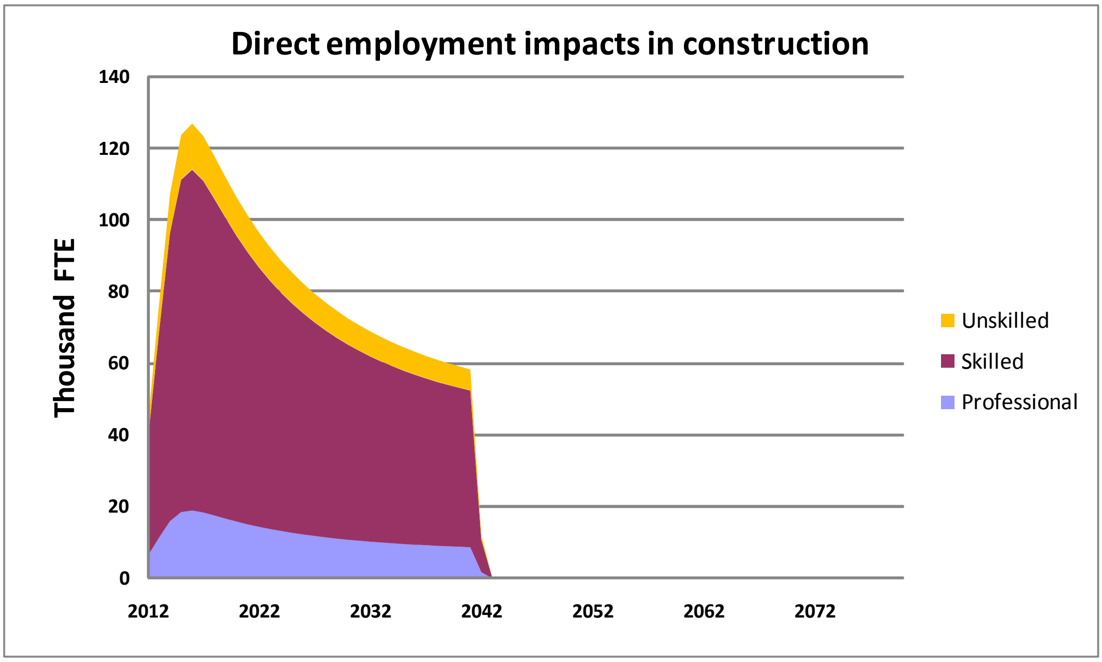

Figure 7-5: Direct employment impacts divided by skill level - *S-DEEP3* scenario

Figure 7-6: Direct employment impacts divided by skill level - *S-SUB* scenario

7.2 Direct (negative) employment effects in the energy sector

Negative direct employment effects are expected to occur on the of the energy sector ("Electricity, gas, steam and hot water" sector, as it is referred to in the Polish Input-Output tables). These have been calculated by multiplying the reduction in energy demand (in monetary units) by the labour intensity of the energy industry. **Table 7-2** displays a *snapshot* of the estimated negative direct effects in the energy sector in 2020, which are much smaller than the positive direct effects in construction shown in **Section 7.1** because of the lower labour intensity of the Polish energy sector.

	S-BASE	S-DEEP1	S-DEEP2	S-DEEP3	S-SUB
Energy savings in 2020 (M EUR 2010)	429	572	932	1,305	643
Direct effects in energy sector (thousand FTE units)	-4	-5	-9	-12	-6
Labour intensity of the energy sector in Poland (FTE/MEUR)	**10**				

Table 7-2: Negative impacts on the energy sector in 2020

By comparing the direct positive and negative employment impacts of **Table 7-2** and **Table 7-1**, it can be seen that for every FTE unit to be lost in energy in the year 2020, some 10 jobs would be created in the construction sector for the deep renovation scenarios.

The employment impacts have also been estimated in the longer term, and represented in **Figure 7-7**. They reflect the increase in energy prices forecasted in **Section 5.1.9** and also the end of the implemention period of each scenario. As the energy savings generated by the improvement of energy efficiency in a building are permanent, the forecasted decrease in employment in the energy sector is also permanent. However, as discussed in more detail in **Section 8.3.1**, this model cannot take into account a series of qualitative observations which would mitigate to some extent the negative effects forecasted in the energy sector.

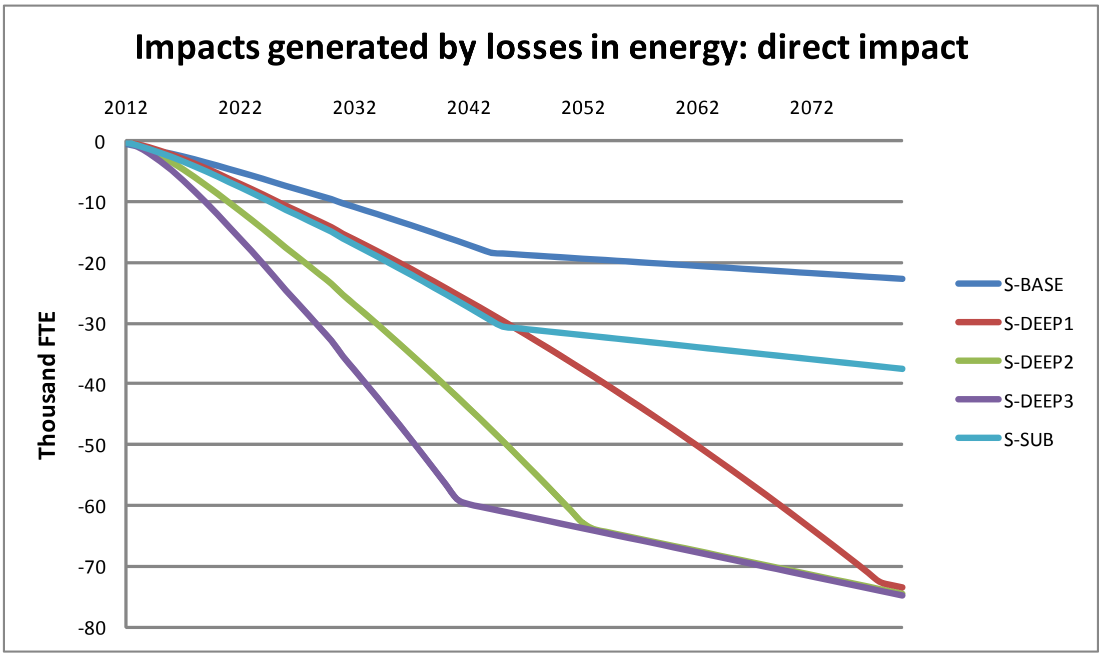

Figure 7-7: Trends of direct employment impacts on the energy sector

7.3 Total employment effects

In order to obtain the **total** employment effects generated by the energy-efficient retrofit scenarios considered in this study, the direct impacts on the construction and energy sectors have been added to the indirect and induced impacts. Positive indirect employment effects are generated in sectors other than construction as a result of the increased demand for construction activities. Negative indirect effects are also expected in the suppliers of energy sector. On the other hand, positive induced impacts come both from the additional disposable income generated by new jobs and from the energy savings experienced by households, which lower their energy bill. Negative induced impacts happen as a result of the income losses experienced by the laid-off workers of the energy sector.

As for the calculation of the additional jobs generated by the intervention scenarios, it must be reminded that the *S-BASE* scenario represents the number of net employments generated by the current baseline retrofits supported by the Thermo-modernization programme. Thus, the calculation of the amount of additional net jobs created by the two intervention programmes (*S-DEEP* and *S-SUB* scenarios) must deduct those that are being currently provided by *business-as-usual* retrofits (e.g., the total additional net jobs created in 2020 by the *S-DEEP3* scenario are 254 thousands FTE, as calculated from the figures in **Table 7-3**).

The Input-Output methodology used to calculate indirect and induced impacts allowed the impacts to be calculated by sector of activity. The Input-Output table used in this study is for the year 2005 GUS, 2009), contains 56 different sectors of the economy: the entire list is compatible with NACE Rev. 1.1, and can be seen in **Section 5.2.5**. Although it may be of some interest to see the impacts in such detail on all sectors of the economy, it is more useful to group the results for a series of macro-sectors. Therefore the following sections will show the grouped results rather than the detailed results by individual sector.

7.3.1 Employment impacts in 2020

Table 7-3 and **Figure 7-8** show the total employment impacts in Poland for 2020 in the different scenarios. The impacts are divided by type: direct impacts in construction and energy, indirect impacts generated by the investments in construction and the reduced demand in energy, and the two types of induced impacts discussed in **Section 4**: those caused by the changes in the labour market (positive impacts from the new jobs created by the investments in construction, and negative impacts from the lost jobs due to the reduced energy demand), and those produced by the additional consumption from energy savings.

The results demonstrate that there is net employment creation in all scenarios. As expected, it is clear from the graphs that total employment impacts are higher for deep renovation scenarios, because the investments are higher. It can be also noted that the total amount of jobs (direct, indirect and induced) generated per unit of investment is also the highest for deep renovations – 42 FTE per million Euros (see **Table 7-3**).

Table 7-4 and **Figure 7-9** show the total indirect and induced impacts in all the macro-sectors of the economy. The results indicate that hundreds of thousands of net additional jobs can be created in 2020 by deep renovation scenarios, ranging from the 86 thousand additional FTE per year of *S-DEEP1* scenario to the over 250 thousand additional jobs created by the more intensive *S-DEEP*3 scenario. Note that, as said above, additional jobs are calculated by subtracting the net jobs estimated for S-BASE scenario (i.e., the ones currently generated by the Thermo-modernization programme) to the ones estimated for the proposed intervention scenarios (*S-SUB* and *S-DEEP*).

It is important to highlight that, as shown in **Table 7-3**, many of the positive employment impacts are due to the indirect and induced impacts of renovation activities (i.e., in the sectors supplying materials and other inputs to the construction sector, plus in all other sectors of the Polish economy positively impacted by the programmes): in 2020, 75% to 80% of the gross positive employment created corresponds to these categories, whereas 20% to 25% are direct employment in the construction sector. By major economic sectors, the largest indirect and induced employment gains can be seen in the following industries (see **Table 7-4** and **Figure 7-9**): community and social services (a very labour-intensive sector), manufacturing (a sector making an important contribution to the program through the supply materials for the renovations) and the construction sector itself (the demand of the construction industry increase because of the retrofits, e.g., new dwellings for the new employees, more facilities for the construction industries implementing the retrofits, etc.).

	S-BASE	*S-DEEP1*	*S-DEEP2*	*S-DEEP3*	*S-SUB*
Million Euros invested in 2020	1,104	2,999	4,997	6,995	2,154
In thousand FTE units					
Direct impacts on construction sector	19	46	76	106	34
Direct impacts on energy supply sector	-4	-5	-9	-12	-6
Indirect impacts from investments in construction	22	59	99	139	43
Induced impacts from additional jobs created by investments in construction	16	42	70	98	30
Indirect impacts from reduced demand for energy	-9	-12	-19	-27	-13
Induced impacts from lost jobs created by reduced demand for energy	-7	-9	-15	-21	-10
Induced impacts from energy savings	3	5	7	10	5
Total net employment impacts in 2020	40	126	210	294	83
FTE per Million Euros invested	36	42	42	42	39

Table 7-3: Total impacts for the renovation scenarios in 2020, by type of impact.

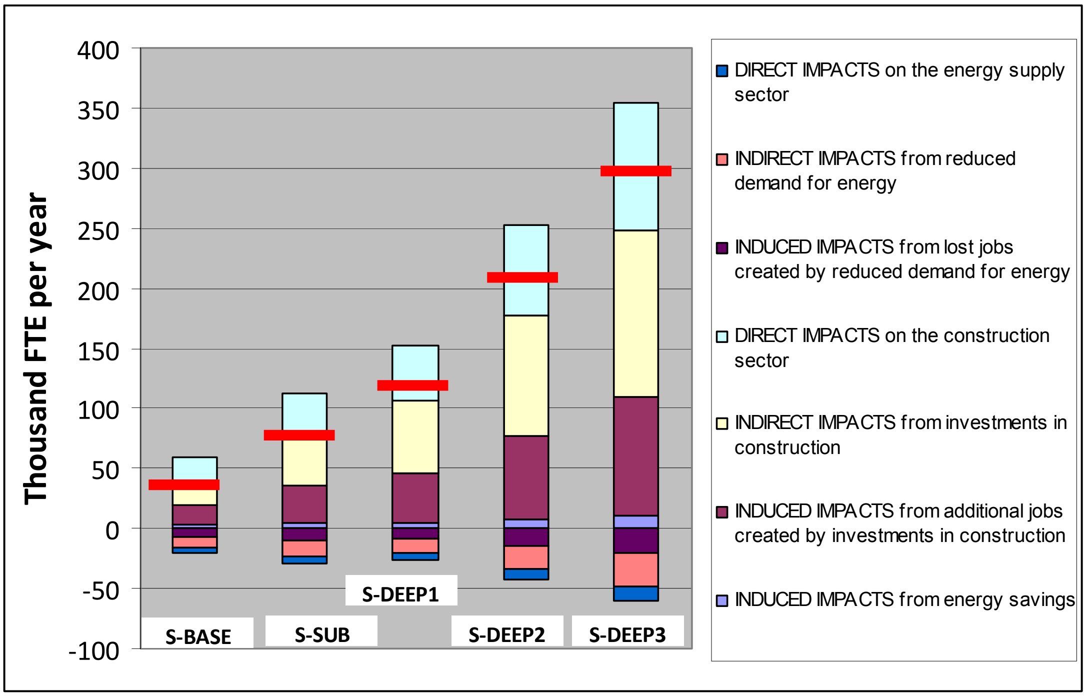

Figure 7-8: Total impacts for the renovation scenarios in 2020, by type of impact. The size of the net impact is marked with the red crossing line.

In thousands FTE units	*S-BASE*	*S-DEEP1*	*S-DEEP2*	*S-DEEP3*	*S-SUB*
Agriculture, hunting, forestry and fishing	1.3	4.0	6.6	9.3	2.7
Mining and quarrying	-1.2	-0.7	-1.0	-1.5	-1.5
Manufacturing	6.6	20.1	33.5	46.9	13.6
Electricity, gas and water supply	-3.7	-4.0	-6.5	-9.1	-5.2
Construction	11.6	32.2	53.7	75.2	22.9
Wholesale and retail trade, restaurants and hotels	1.5	4.5	7.6	10.6	3.0
Transport, storage and communications	0.8	2.8	4.7	6.5	1.8
Finance, insurance, real estate and business services	1.2	4.3	7.2	10.1	2.7
Community, social and personal services	7.3	23.5	39.3	55.0	15.5
Total net employment impact in 2020, all sectors	25.4	86.8	145.0	203.1	55.5

Table 7-4: Indirect and induced impacts for the renovation scenarios in 2020, by macro-sectors.

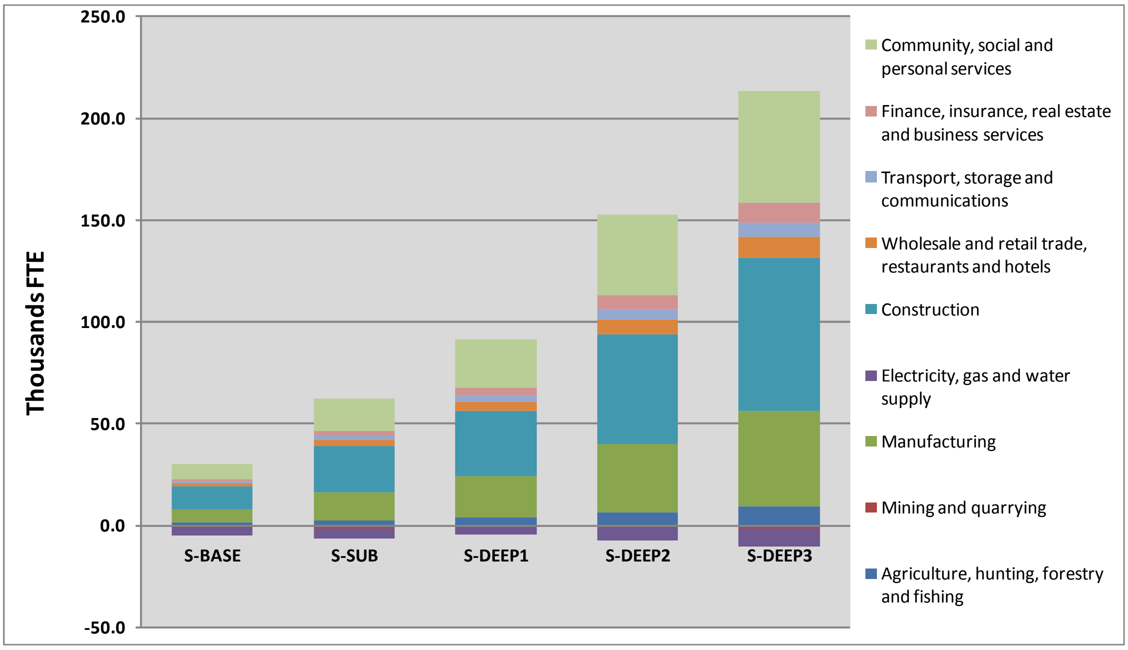

Figure 7-9: Indirect and induced employment effects of the increase in demand in construction in 2020, by macro-sector

However, for the case of indirect employments generated by the programme in the manufacturing sector, it must be noted that the model used for base, suboptimal and deep renovations the I/O coefficient that links the construction sector with the manufacturing and imports sector. However, it is likely that energy efficiency renovations – above all deep renovations in the beginning of the programme – demand more imported materials than the average construction sector. Since no specific I/O coefficients are available for sub-sectors within the construction industry, a certain error has to be assumed in these estimates. As a result, the indirect employment effects of the programme in the manufacturing sector may be overestimated, especially those of deep renovations.

7.3.2 Short and medium-term trends of total employment impacts

The evolution of employment impacts throughout the years is presented in order to explore the effects of two important assumptions of the model: the initial ramp-up period and the learning factor, both of which have an influence on the employment effects. **Fig. 7-10** shows the employment effects of all scenarios until the year 2028, when all the scenarios are still active.

The initial ramp-up period of 5 years is reflected in the increase of impacts until 2016. At that point, the learning factor becomes more influential: the decrease in the price of the retrofits – which is nevertheless taken into account since the start – brings down the total number of jobs created yearly by the intervention. This follows the same rationale presented for direct Impacts: economies of scale productivity increases make it possible to renovate the same number of buildings at a lower cost, which implies a smaller number of workers and also a smaller quantity of intermediary inputs (e.g., energy, construction materials, transport, etc.) per retrofitted unit.

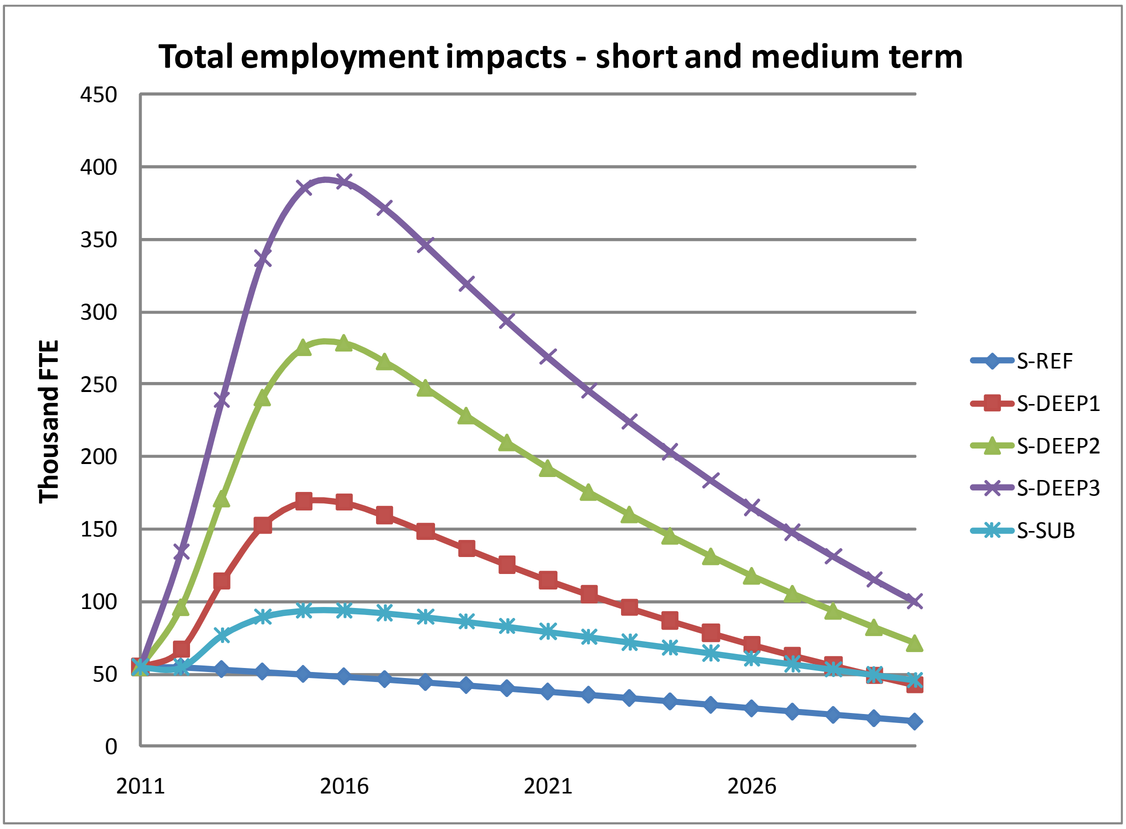

Figure 7-10: Short- and medium-term view of the net employment impacts in different scenarios

7.3.3 Long-term trends of total employment impacts

Even though the building stock and employment mode used in this research allows showing long-term trends, it must be noted that such forecasts carry a higher degree of uncertainty due to changes in technology and costs, in the financing of the program, fluctuations in the global economy, etc. All may contribute to alter the results of the model in the long term.

Acknowledging that as a limitation of the model, **Figure 7-10** displays the evolution of the forecasted effects until 2041. The substantial mid-term decline in the net amount of jobs forecasted by the model is due to the direct, indirect and induced negative employment effects related to the energy savings (for all scenarios) and also to the reduction in the per unit renovation costs that is expected to happen only in *S-DEEP* scenarios. Most of those job losses occur as indirect and induced negative effects (in 2020, around 80% of the gross negative employment effects are foreseen in these categories for all scenarios). It is worth noting that not very significant job losses (up to a maximum of 6% of gross job losses in 2020, depending on scenarios) occur in the mining and quarrying sector. This is a particularly sensitive sector for

Poland in terms of its employment losses, as proven by the resistance of organised labour unions to mine closures during the transition period (Suwala, 2011). Other than that, the energy sector is the one recording, as expected, the largest (direct, indirect and induced job losses) see **Table 7-4** and **Figure 7-9**.

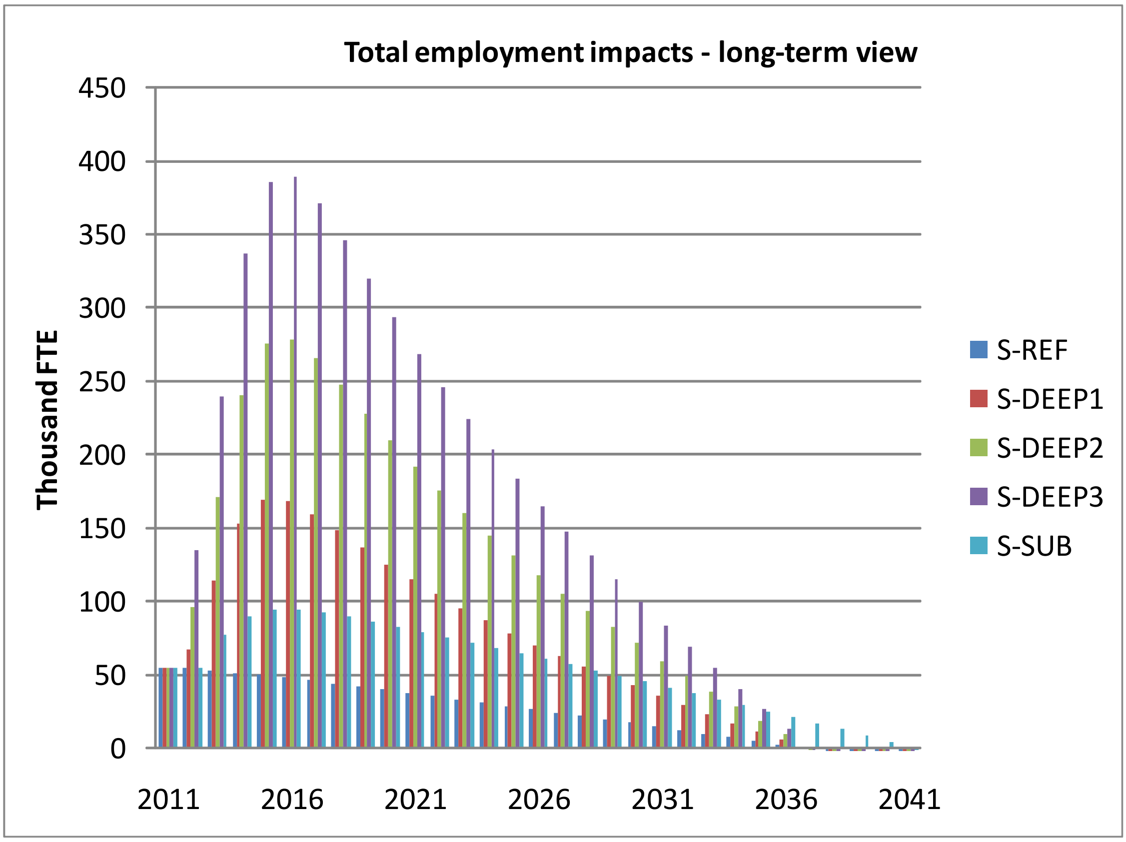

Figure 7-11: Long-term view of total net employment impacts in the different scenarios

However, it can be argued that in long term there is bound to be an increase in induced effects generated by energy savings: building owners will have repaid the investments originally required to perform the energy-efficient renovations, and will be able to fully enjoy the energy savings without having to dedicate part of the savings to the loan repayment. This boost in disposable income will allow households and public building owners to increase their consumption which will generate additional jobs through increased demand for goods and services. Besides, an update of the retrofits is required after a number of years, possibly at a lower cost than the first retrofit, in order to keep the energy performance of the retrofitted buildings. Though not incorporated in the model to avoid further complexity, these *second round* retrofits would also contribute to keep employment levels (but also demand additional investments). Finally, as discussed in **Section 8.3.1**, the decrease forecasted in the energy sector is may not be as large as predicted by the Input-Output model mostly because of the importance of fixed capital costs (as compared to labour costs) in the structure of the energy sector.

7.4 *Sensitivity analysis*

A sensitivity analysis was performed on a two model input data identified in **Section 5.4**. To quantify the sensitivity of the results to those, tests were performed by allowing each selected parameter to vary in a specific interval. The consequent variation of the total employment impact was then displayed on the results of *S-DEEP2* scenario, which is deemed as representative of the deep renovations targeted with this study.

Variation of the learning factor. As discussed in **Section 5.1.7**, the learning factor has been considered in the model to reflect the fact that firms and workers learn the new deep renovation technologies, and economies of scale enter into play. Various assumptions about the learning factor have a significant impact on final results. If the learning factor is higher, productivity will quickly increase, therefore fewer workers will be necessary for renovations in the mid-term. On the other hand, if the learning factor is lower, there will still be a high need of workers for performing the retrofits even in the middle and long-run.

The working assumption was that costs decrease by 8% initially, to gradually reach double the baseline renovation costs. Błąd! Nie można odnaleźć źródła odsyłacza. shows how the final results change if the initial decrease in 2011 is 4% and 10% respectively.

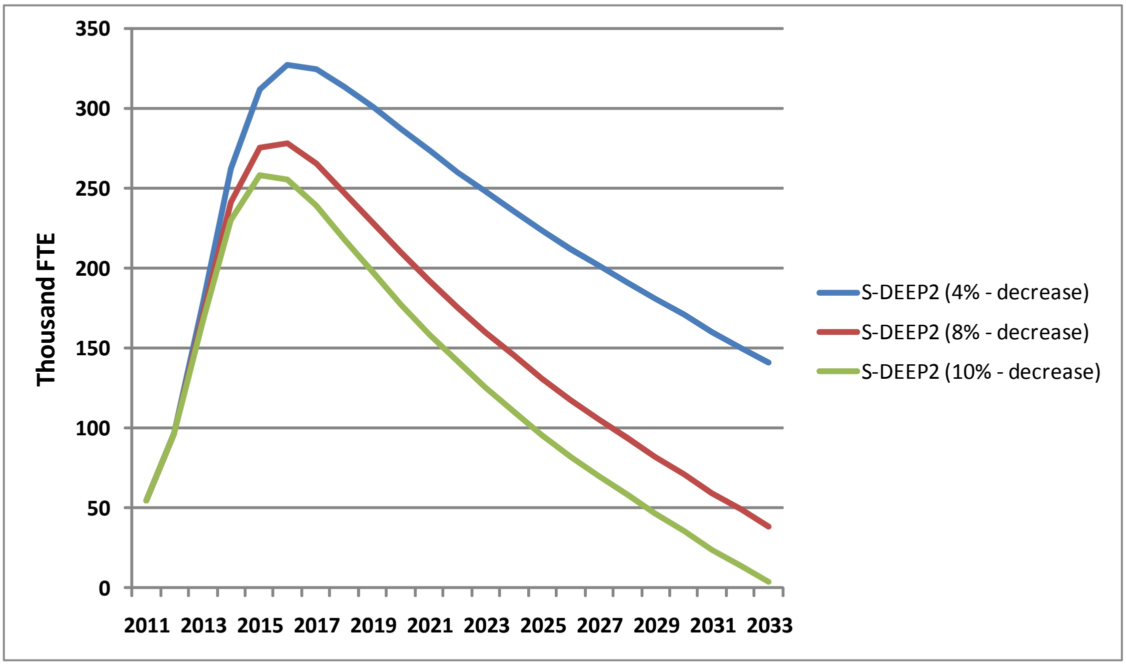

Figure 7-12: Sensitivity analysis – effects of the initial learning factor on the employment results

Variation of the initial costs of the retrofits. It must be noted that while numerous case studies have been considered for this research, no single case of deep retrofit in residential or public buildings could be located for Poland. Therefore, there is still a significant uncertainty surrounding the estimates of the costs for deep renovation interventions in Poland. A sensitivity analysis has been performed, in order to assess the reaction of the final results of the model to a change of deep renovation cost estimates at the beginning of the programme (2011) between -20% and +20% of the estimates used.

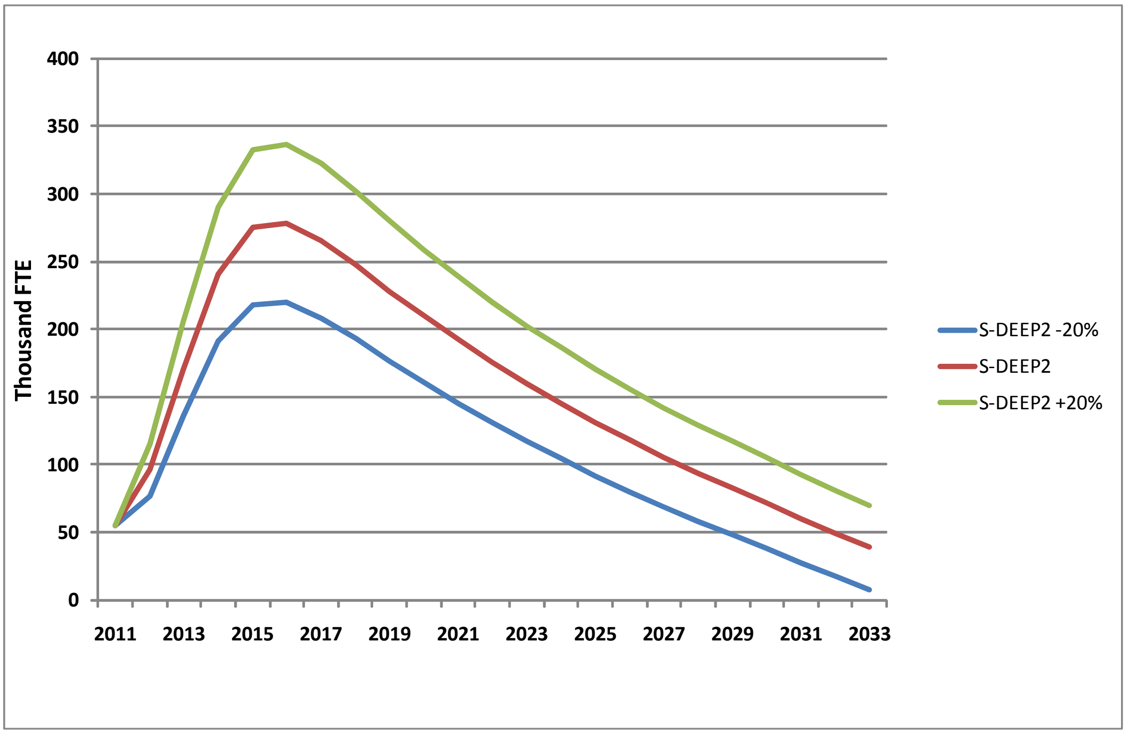

Figure 7-13: Sensitivity analysis – effects of the initial retrofit costs on the employment results

As can be seen from **Figure 7-13**, there seems to be a 1:1 proportion between the variation of total employment results and the variation of the price of deep renovations (i.e., an increase or decrease by 20% of deep renovation costs will cause a 20% change in the final employment effects calculated by the model). This is a source of uncertainty surrounding the costs of a hypothetical deep retrofit programme that has to be surely taken into consideration if the conclusions of this report are applied for re-defining Polish energy efficiency policies.

7.5 Comparison of results with the literature

Given the importance placed by governments to the employment impacts of policies and investment programme, numerous studies estimating the employment effects of such interventions have been produced. A number of these studies – most of them associated to energy efficiency, renewable energy or climate change mitigation interventions – were reviewed for the Hungarian study (Ürge-Vorsatz et al., 2010). The reviewed studies were also deemed as useful for a comparison of the results obtained for Poland in this research. A set of summary tables condensing the conclusions of the reviewed papers can be found in Annex A.

With some exceptions that reported results as jobs created per MWh of energy produced (PV Employment, 2009;p EWEA, 2008; 2009), the vast majority of these studies evaluate employment impacts by estimating the number of full-time equivalent (FTE) jobs created by an investment equivalent to 1 million of the currency considered (e.g. U.S. Dollars, or Euros). Since all studies give results in their own currency, all the results have been harmonised in full-time equivalent (FTE) jobs per 1 Million Euro invested in the year of the study to allow the comparison with the estimates obtained for Poland and Hungary.

One first conclusion of the review is that all studies agree that the proposed measures have positive net employment impacts, which range from less than 10 to around 30 jobs per million Euros invested. Then, as presented in **Figure 7-14**, it was found out that the results obtained in the *S-DEEP* scenarios of the Hungarian and Polish studies are above the averages reported by the literature review.

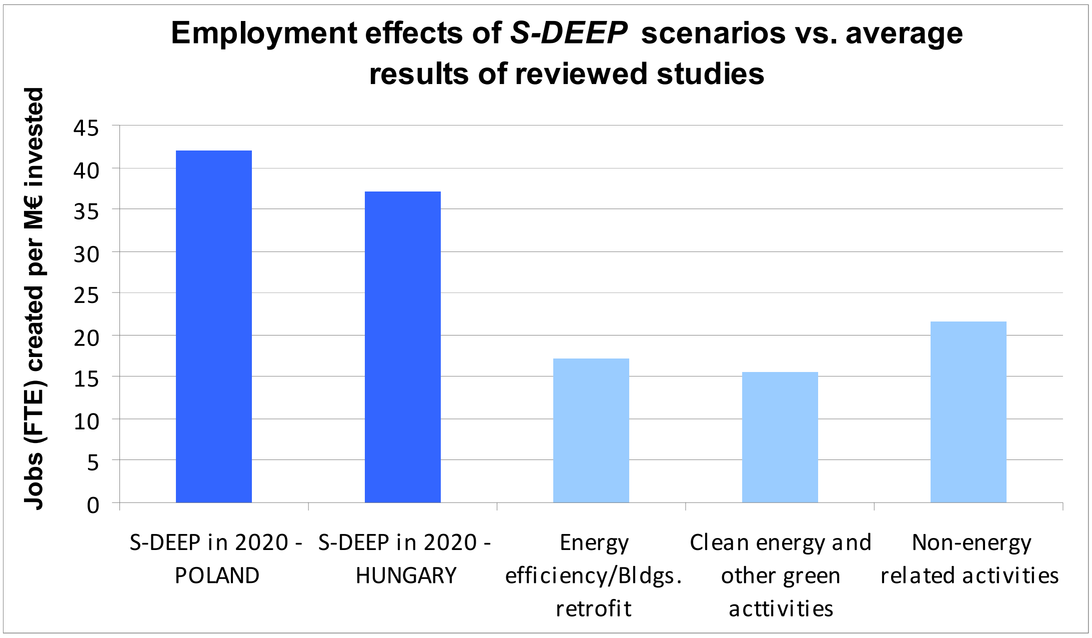

Figure 7-14: Comparison of employment effects of S-DEEP scenarios in Hungary and Poland with other climate, energy and non-energy related interventions

This divergence, which is significant but not excessive (e.g., two of the studies located in the literature review reported figures of 70-80 jobs per million Euro) may be at least partially explained by the fact that in transition economies the labour intensity of the economy is typically higher than in other regions as the relative price of labour is lower than the price of capital and technology. As explained by Rutovitz and Atherton (2009, p. 29), “broadly, the lower the cost of labour in a country, the greater the number of workers that will be employed to produce a unit of any particular output, be it manufacturing, construction or agriculture. This is because when labour costs are low, labour is relatively affordable compared to mechanized means of production. Low average labour costs are closely associated with low GDP per capita, a key indicator of economic development”. In this regard, it is worth noting that practically all the studies reviewed were completed in high-income countries, most of them in G7 nations.

8 Additional aspects: wider effects of retrofits, co-benefits and financing

8.1 Geographical and temporal distribution of employment effects

8.1.1 Geographical distribution of employment effects

While evaluating the employment effects of a national investment programme, one important question to consider is the location of the impacts that are expected to take place. Jobs might be created or lost throughout the country, or in and around economic centres or suitable sites. The construction of a nuclear plant, for example, is likely to generate many jobs around the place where the plant is built and operates, but will have a much smaller impact in other regions.

The model used for estimating the employment effects of the proposed intervention scenarios does not allow obtaining results at the sub-national scale such as the *voivodeship* (province) level. This has to do first with the goal of the research, which aimed at producing aggregated results at the national level, and second with the limitations posed by the input data of the combined building and employment model. Regarding the latter, only aggregated data (representative for the whole Polish building stock) could be gathered on the characteristics of residential and commercial buildings. Equally, the Input-Output tables and labour intensities used for the estimation of direct, indirect and induced effects were only available at the national level.

This said, it can be suggested that building retrofit programmes such as the ones studied in the present research are likely to have direct, indirect and induced employment impacts distributed throughout the country for various reasons.

First, buildings to be renovated are as geographically disperse as the population. Thus if we assume the proposed renovations will conducted by local small- and medium-size enterprises (SMEs), it can be forecasted that direct employment effects would be distributed evenly across regions. It must be acknowledged, however, that the higher technical complexity of deep retrofits (as compared to baseline and suboptimal) may produce some concentration of the employment effects around the areas where more capable companies, those able to execute satisfactorily such a retrofit, are located.

As for the indirect effects, there may be some regional concentration in the construction materials industry in the first place. If the increasing demand for materials (e.g., double- or triple-glazed windows, high-quality doors, insulation materials, etc.) expected as a consequence of the programme brings in new companies producing those intermediate inputs, the regions where such factories will be located would also be benefited from the perspective of the programme's employment effects. Besides, since construction materials are also imported, especially in advanced retrofits, this may lead to a transfer of indirect employment effects (perhaps not properly captured by I/O analysis) beyond the borders of the country (see **Section 7.3**).

Finally, it is expected that induced effects are the most widely distributed employment impacts because the additional income coming from the additional wages in the construction sector plus the energy savings will be spent by households living all over the country on a wide range of goods and services produced in many different regions.

Some conclusions of previous studies support these assumptions. This, way, an analysis of various energy efficiency initiatives implemented under the SAVE programme in EU Member States in the mid-1990s highlighted positively the geographical dispersion of their employment effects and the likely participation of small local firms (Wade et al., 2000, p. 38). A related study in the UK also pointed at these aspects, stressing the geographical overlapping between fuel poverty and high unemployment (EST, 2000, p. 40): "work in manufacturing and installing energy efficiency measures is accessible to people who suffer the highest rates of unemployment in the UK, given that it is manual labour, and the work is dispersed across the country. Indeed, where programmes aim to assist the fuel poor the work is concentrated in areas where unemployment tends to be highest". And Baillie et al. (2001) stressed the fact that energy savings stimulate local economy because the additional available income are usually transformed into a wide range of small purchases – often at local level – that increase the demand of all sector across the economy. Even in U.S. States where the fossil fuel industries are strong, the authors of the latter study affirm that job losses in these industries and their suppliers are more than compensated by employment gains in all sectors, so that overall employment effects are positive and widely distributed throughout the country.

8.1.2 Temporal durability of employment effects

Even though climate change mitigation measures often report positive employment effects (see **Section** 7.5), it is reasonable to ask to what extent these net job gains can be sustained for long periods of time or if, on the contrary, they tend to disappear once the measures have been implemented.

The model used in this research allows, unlike with the geographical distribution of the employment effects, a results-based analysis of their temporal durability. This is particularly relevant in this study because of the impact of the learning factor in the mid- to long-term on the positive direct, indirect and induced employment figures, and also because of the job losses forecasted for the energy sector. This analysis is carried out for the several decades through which the intervention is expected to proceed.

As shown in **Figure 7-10** and **Figure 7-11**, the model predicts a gradual but steady decline in total net employment figures, with all scenarios (including the baseline) producing negative results from around the year 2040. This results from the forecasted increase in the price of domestic energy carriers (i.e., the larger the energy savings, the larger the job losses in the energy and its supply chain-related sectors) and also from the learning factor in the case of *S-DEEP* renovations (i.e., the lower the investment needed per unit for deep retrofits, the smaller the number of jobs created in the construction and its supply chain-related sectors). This is very much in line with the literature, which predicts that in the short term, when workers move from high-carbon to low-carbon activities, net job creation is expected as the former are often more labour-intensive than the latter. However, as technologies mature and become cost-efficient (i.e., they reduce the amount of input – capital and labour – needed for producing a given amount of output) employment gains cannot be sustained (Fankhauser et al., 2008).

Then, by the time the renovation programme has ended and the direct, indirect and part of the induced effects – those coming from wages of additional workers in the construction sector – disappear, the job losses in the energy sector, which that accumulate throughout the implementation period and remain afterwards, will mostly prevail.

However, this general trend in the results produced by the model can be discussed from three points of view.

First, the fraction of the induced effects stemming from energy savings will be operating and actually increasing (because of the increase in energy prices) throughout and beyond the implementation period. This happens because after the end of the repayment period, building owners will be enjoying the 100% of the energy savings achieved by the renovation, and not just the 20% that they were getting back while repaying the loan (as defined in the simplified financing scheme assumed in the model). While this was not incorporated into the model to avoid further complexity related to the financing of the retrofits, this indicates that a programme like the ones proposed would provide additional employment that do not vanish once the renovation programme is completed.

Second, the job losses of the energy sector are likely to be overestimated by the Input-Output analysis, which assumes a lineal relationship between the output and the labour of the energy sector.

Third, it can also be argued that the length of the programme ensures the long-term character of the employment effect, which will last for several decades even in the most ambitious scenario (*S-DEEP3*). Besides, the over 30 years needed for completing the programme under different scenarios are not far from the active lifetime of a construction worker. In fact, as presented in **Figure 7-10**, the less ambitious is the scenario in terms of number of units renovated per year, the longer it takes to renovate all buildings in Poland and the more gradual is the reduction in total net employment figures. This offers an argument from the perspective of the durability of the employments effects for supporting a scenario with low renovation rates.

In any case, policy makers should consider that after and during the program there might be workers who will be redundant because of the fall of labour demand in the construction industry. This cannot be avoided and it is a feature of any large-scale program. A relatively straightforward solution that would ease this problem would be making the program not to finish from one day to the other but foreseeing a ramp-down period so the large masses of workers employed in the construction sector will not lose their jobs at the same time but throughout a longer number of years.

Finally, in the longer term and from a wider perspective, it can be argued that in an optimistic scenario with an ambitious global climate commitment, the proposed retrofits would be accompanied by a whole range of mitigation measures and policies aimed at largely reducing emissions of the Polish and world's economies. In that context, mitigation policies would start a wave of innovation in which, through a process of creative destruction, economic agents will relocate themselves in the new context. Though practically no evidence exists on the long-run job creation effects of a transition to a low-carbon economy, growth theory has identified skill-biased changes and innovation as major drivers of economic growth. It is thus believed that the structural changes needed could be of a similar order of magnitude as those introduced by the invention of the steam engine, modern transport, computers and the internet. On the other hand, this would be hindered if low-carbon research and innovation would occur at the expense of (and not complementing to) innovation in non-energy sectors offering higher social and financial returns (Fankhauser et al., 2008).

8.2 Effects on the labour market of the construction and other sectors

8.2.1 Considerations on the supply of labour

The results obtained in **Section 7** show that should a deep retrofit programme be established, the construction industry will need a large amount of additional workers at its peak – in the range of the 340 to 120 thousand FTE per year (105 to 35 thousand in the construction sector alone). It might then be questionable whether there is a sufficient supply of workers in Poland to satisfy the enhanced labour demand.

The following elements of the labour supply have been also analysed in order to foresee possible bottlenecks in the implementation of the programme.

Entrepreneurs. It can be assumed that the construction industry has a low cost of entry, and that many of the companies operating the building renovation sector are small and medium enterprises (SME). According to Eurostat, in Poland, the industry is mainly composed of SMEs, with an average of 3.9 employees per company in 2008. It is not likely to see a shortage in supply of entrepreneurs wishing to take advantage of the benefits of such a large-scale programme, though conditions need to be in place to facilitate their participation (e.g., low cost of entry in the market, smooth administrative procedures, access to credit for newcomers, etc.). This is crucial for the competition in the sector, and thus for ensuring that the retrofits are delivered at the foreseen costs.

Attraction of semi-skilled and unskilled workers. The construction industry is a labour-intensive sector in which the skills level of workers is usually lower than in other industries. It is also known that most of the jobs resulting from buildings' energy efficiency renovations are in manual occupations (Wade et al., 2000) but, as seen in **Section 7.1**, in the case of deep renovation the demand of skilled workers is substantial.

In principle, it is believed that the additional labour created by the programme can be supplied by the unemployed and inactive Polish. The inactive population of Poland was around 9.1 million people in 15-64 age range. Of those, some 1.6-1.7 million people were willing to work but not seeking employment at the moment (Eurostat, 2011b). In addition, there were around 1.7 million of unemployed people in Poland in the same year (Eurostat, 2011c), which would be the ones more ready to be to activity because by definition they are currently looking for an employment. This makes a pool of some 3.3 to 3.4 million people that would be more or less ready to take the up to 254,000 additional jobs per year forecasted by the model for the peak year of the most ambitious deep renovation scenario (*S-DEEP3*). Though not all of them will have the required skills – especially if deep renovations require, as modelled, a higher proportion of skilled workers – it is expected that there would be no constrains on the side of the labour supply to meet the expected increase in employment levels.

Training of professional and skilled workers. The demand for workers will be spread across all skill levels. In the case of direct employment, there will be a need for new construction entrepreneurs, for college-trained professionals (such as architects and engineers), skilled workers (e.g. plumbers, electricians, painters) and for unskilled labourers. However, as presented in **Figure 7-3** to **Figure 7-5**, a higher proportion (as compared to baseline and suboptimal renovations) of the new employments created by *S-DEEP* scenarios will be for skilled construction workers and also for architects and professionals of a similar skill level.

University courses already teach architects and engineers the background theory that will help them plan and build energy-efficient buildings. It can be expected that such a programme would create an interest in students (especially if it is advertised well in advance). Current architects can be taught the principles of deep energy efficiency (such as passive house) planning. In the same way, skilled workers may learn the techniques needed to build or retrofit a dwelling to a high energy efficient standard, as the technologies already exist and are not much different from what the workers are already used to.

Because of this need to train and retrain the labour force to be involved, the employment model included a 5-year ramp-up period, during which the construction industry adapts to the new demand and respond to a possible shortage of supply in workers or skill. However, this requires changes in the curricula of subjects taught at higher education centres and vocational schools, the provision of specific training courses for skilled workers, etc. and ultimately the involvement of the State.

The other element currently scarcely available is real-life experience: once gained the theoretical knowledge, professional and skilled workers need to apply it to actual projects in order to learn to deal with issues that may not be considered in the theory. The model used reflected this process by the introduction of a learning factor that will progressively decrease the costs of deep renovations until reaching a mass-production price level.

Gender composition of new employment. It can also be mentioned that construction work may not be seen as an attractive employment for the part of the working age population – namely women – given that most employees in the construction sector are men. Thus is it is expected that most of the new employees in the construction sector will be men, at least in the unskilled and skilled workers-level (new positions at the architect/engineering level are more likely to be filled by women as well as men). On the other hand, the programme will also have large indirect and induced impact on other sectors such as *Community, social and personal services* (see **Figure 7-9**) where the proportion of female employment is higher, thus helping to balance the gender composition of the new employment created.

Age composition of labour in the construction sector: demographic issues. As discussed in **Section** 2.3, the Polish society is aging progressively, which has important effects on the long-term balance of pension funds (i.e., the numbers of workers contributing to pension funds per pensioner is expected to decrease towards the middle of the century).

This issue also affects the composition of the whole Polish labour market and must be taken into account for a long-term intervention such the one analysed. At this point, it can be suggested that thanks to the improvements in health conditions and life expectancy, more people over 60 will be economically active in the coming years, as retirement ages will also increase progressively. However, this is not likely to make a big difference in the construction sector, where most of the work needs physical strength.

Internal mobility of workers. As discussed above the direct effects should mostly be distributed throughout the country, so a high need for mobility is not expected.

Inflow of foreign workers. The forecasted increase in Polish employment levels that would follow the implementation of retrofit programmes is likely to attract foreign workers, probably more for the unskilled jobs segment.

In Poland, a country that had been a net sender of migrant workers throughout the 2000s, this trend has inverted in the last two years, for which a crude rate of net migration as reported by Eurostat has been around 0% in 2009 and 2010 (Eurostat, 2011d). In the year 2009 the total inflow of foreigners reached the number of 56,000 persons, of which 7,700 persons were of age less than 14 and 2,300 persons were 60 year or older. This roughly results in a potentially working-age population of 46,000. Most of this inflow of foreign citizens originated in other EU-27 Member States, the countries of the former USSR and Asia (Statistical Yearbook 2010). This may be the initial composition (by region of origin) of the foreign workers benefited by the programme.

The informal labour market. About 9,5% of the total number of Polish employees works in the *grey zone* of the labour market. Unregistered labour is more common among young persons with no low educational achievement, i.e. those having the smallest chances for official employment. For example among persons with education below basic vocational, the percentage having their main employment en the grey zone reaches 17% ,while among persons having vocational secondary education this rate falls to less than 8%. Among persons with a university degree this is 3% (Polska 2030 – Wyzwania Rozwojowe – Chancellery of the Prime Minister 2009)

The construction sector is certainly not immune from this phenomenon, and it is in fact likely to be one of the most affected industries. On the whole, the effects of such a large-scale programme on the informal labour market would require a much more in-depth analysis. However, it can be hypothesised that the initial scarcity of qualified labour might give more contracting power to the employees, forcing the employers to declare all the wages or register the workers for social security. The programme may actually offer an opportunity to reduce grey labour in the construction sector. Since the State would take an active part in its implementation and allocate part of its budget for financing the renovations, it may also want to ensure that taxation and social security rules are respected by construction workers and enterprises in the case of new direct jobs created as a result of the programme. This is important for the perspective of the fiscal impact of its implementation (see **Section** Błąd! Nie można odnaleźć źródła odsyłacza.**1**).

8.2.2 Considerations on the effects of wage changes

A large scale programme like the one envisioned in this study is very likely to have an effect on the whole labour market which can materialize not only in the demand for many jobs, but also in the secondary effect of this demand: an increase of the wage levels in the country. If the additional demand for labour is successfully met by unemployed, inactive and migrant workers, as discussed in the previous section, wages increases related to labour supply constraints may be avoided. But it is not clear to what extent this would is possible. First, the skills of the unemployed and inactive may differ from those needed in the retrofits, especially for skilled labour, the most demanded sort of employees. In addition, the unemployed and inactive may decide not to work for the wages offered in the construction sector because of their high reservation wages. Thus they would be willing to work only if the offered wages were higher.

In the case of a wage rise related to the additional demand of labour in the construction and related sectors, the costs of retrofit projects will increase (hence of the whole programme) and perhaps the rate of renovations will slow down. In addition, an increase in the wages of the construction sector can have *splillover* effects on other sectors that compete for the same workforce, which would result in a general wage increase having adverse effects on the whole labour market and in production costs increases in other industries. The net effects would have to be estimated in a more complex framework because, on the other hand, higher wages also imply additional consumption of the households whose members keep their employment in spite of the wage level increase – and therefore, additional induced effects from that consumption.

One possible outcome is a combination of supply and demand effects: in the short term, when labour is in short supply, wages will increase, with the effects mentioned above and a slow *start-up* of the programme. In the medium term, more workers will be attracted to the industry and the costs and renovation rate will stabilise, with the productivity of workers progressively rising due to learning factors. In the longer term, the model forecasts a progressive decrease in the demand of labour of *S-DEEP* scenarios as deep renovation costs decrease, which may bring down wages again as the demand of workers is reduced. Finally, in all these stages higher wages bring about higher levels of consumption which may partially offset the negative effects of wage increases on total employment levels.

One way to quantitatively estimate the effects of an wage increase in employment levels is through the wage elasticity of labour demand, which indicates the reduction in labour demand (i.e., amount of labour required by a sector or an economy) that follows a certain increase in the wages paid, e.g., in the Hungarian study (Urge-Vorsatz et al., 2010), a wage elasticity of labour demand of 0.3 was found, which means that a 10% increase in wages would result in a 3% reduction in labour demand.

8.3 Effects on other sectors

8.3.1 The energy sector. The rebound effect.

The energy sector has a low labour-capital ratio. This implies that relatively less labour than capital is required by energy supply industries to deliver one unit of output. Thus, as presented in **Table 7-1** and **Table 7-2**, the labour intensity of energy supplying activities (10 FTE per million Euro) is below the estimated labour intensity of deep renovations (15 EUR per million Euro). This is the main reason why on the whole the net employment impacts are positive in the short and middle term

However, direct negative employment effects are expected on the energy sector because of the energy savings generated by building retrofits. As estimated by the model, some 60,000 to 70,000 FTE per would be lost per year at the end of the implementation period of *S-DEEP* scenarios (see **Figure 7-7**). These job losses would remain and even increase according to the results of the model once the building stock has been *turned* over because the energy savings are permanent. This makes in the long run (beyond 2040) negative net employment effects are forecasted because the permanent job losses in the energy sector are cannot be totally offset by the permanent energy savings-related induced employment effects (see **Figure 7-11**). As explained in **Section 7.3.3**, these estimates obtained from the model do not consider that households will enjoy 100% of the energy savings once the initial investment costs have been fully repaid, which overestimates the long-term net negative employment effects of the programme.

There are nevertheless several additional reasons why direct job losses in the energy sector are thought to be overestimated by the model:

- The energy sector is characterised by its large fixed costs, i.e. a fixed amount of labour and capital is required to keep the system running (power plants, pipelines, grids, etc.) independently of the amount of energy delivered. On the other hand, the I/O methodology calculates employment effects assuming a linear relationship – defined by a labour intensity expressed in FTE per thousands PLN – between the output and the amount of employees of each sector. This might not be a realistic description of how economic sectors react to changes in the demand, especially when those changes are not marginal. Thus a large reduction in energy demand, such as the one expected in *S-DEEP* scenarios, may result in a less than proportional (i.e., smaller than estimated in the model) reduction of the workforce. Because of this reason as well, job losses in the energy sector are likely to happen in *lumps* (e.g., when a power plant is forced to close because of the reduction in energy use). In the case of *S-DEEP* scenarios, this poses a collateral question on the future of district heating (DH) systems, currently providing 42% of the heat demand of Polish residential and commercial buildings and whose demand for heat would be drastically reduced once the dwellings connected to a DH plant are renovated to a high efficiency level.

- The energy that is not needed in the domestic market might also be exported, if regional and world markets are ready to accept the increased supply of Polish fuels. Exporting allows offsetting part of the forecasted job losses in the energy production sector to be offset. Such argument would apply especially to coal – Poland is a net exporter (Suwala (2010) – and domestic natural gas, but of course not to imported natural gas.

<u>The rebound effect.</u> Further effects need to be taken into consideration as well. As described in the literature, an increase in energy efficiency implies a better use of the energy but does not always result in as less energy consumed as expected.

The so-called *rebound effect* happens as a consequence of a shift in the demand of energy, which may rise following a the drop in energy prices (price effect), and because energy savings will increase the money available for consumers (income effect), which in turn will intensify the consumption of other energy-consuming goods and services (Greening et al., 2000; Nässén and Holmberg, 2009). Although the rebound effect is a concept well-rooted in economic theory, its actual size is a matter of discussion. In the residential sector, reviews indicate a rebound effect of 10 to 30% (of the energy savings initially forecasted) for space heating, less than 10% to 40% for water heating and 5% to 12% for lighting (Greening et al., 2000).

For this study, the model's results can be analysed from the perspective of the two components of the rebound effect:

- Price effect: the model assumes a general increase in the prices of all energy carriers – and not the decrease predicted by the rebound effect – used in Polish buildings for space and water heating, as presented see Section **5.1.9**. This is thought to be consistent with the general trend of energy prices in world markets.

- Income effect: a proper estimate of the additional energy use derived from the goods and services (other than energy) purchased with the energy savings needs to be donbe through the energy intensity of the economic sectors benefited by the increase in households' consumption. Though such estimation lies beyond the boundaries of this research, an assessment of California's existing and proposed energy efficiency policies (Roland-Host, 2008) concluded that the induced jobs stemming from increased households' consumption were mostly created in low energy-intensity sectors. In our case, the size of this type of rebound effect would be limited given that building owners only receive a 20% of the estimated energy savings for several decades.

8.3.2 Other sectors of the economy: manufacturing

An intervention of the magnitude such as the one proposed is expected to have effects in all the sectors of the economy via indirect and induced effects. All sectors of the economy but the energy suppliers will actually benefit – the model reports larger output and employment figures – from the increased demand of households and the construction sector. At the same time, the increase in wages discussed in **Section** 8.2.2 may also affect sectors other than construction if the increased demand of labour cannot be satisfied by the unemployed and the inactive population.

Special attention should nevertheless be paid to the sectors manufacturing the construction materials and equipments (e.g. triple-pane windows, heat exchangers, advanced thermal insulation, etc.) needed for deep renovations. As in the case of the skilled labour, the demand for such intermediate inputs would grow substantially as a result of the programme. If the supply does not react at the required pace (i.e. new producers entering the market, existing companies starting new production lines, etc.), materials would become another bottleneck that may increase the costs of deep renovations.

8.4 Additional co-benefits of energy efficiency in buildings in Poland

8.4.1 Fiscal effects, social security spending and enhanced economic activity[C4]

As the current sovereign debt crisis experienced by some EU Member States has shown, maintaining the balance between government revenues and expenditures is crucial to ensure the overall stability of a national economy. A large building renovation programme such as the one proposed in the deep efficiency scenarios would have two positive fiscal impacts on the balance of the Polish government budget:

- Less expenditure because of the unemployment benefits that wouldn't have to be paid (at least to the extent that the new jobs are taken by previously unemployed population receiving such benefits). Lower expenditure in social welfare programmes can be also expected if the additional employment created manages to increase the disposable income of households benefiting from such programmes. Additionally, a marginal improvement can be expected in the form of energy savings achieved in public buildings. Even though this may have only a minor effect at the national level, it could certainly alleviate the finances of local administrations.

- Higher revenues in the form of personal income tax (because of increase in the employment rate of the economy) and consumption tax (e.g., VAT). This is a direct effect of the changes in Poland's economy in a retrofit programme, which reduces a national economy's imports (thus also improving its trade balance) and enhances investment and consumption within its borders. However, it must be also taken into account the decrease in government revenues associated to less energy consumption (VAT and other taxes levied to energy carriers). The final size and sign of the aggregated fiscal effect are beyond the scope of this study and should be estimated with specific simulation models.

Though evidence of the fiscal effects is still lacking, a recent study of the fiscal effects of Germany's KfW CO_2 Building Rehabilitation Programme, has found out that for each euro invested public authorities get back 4 to 5 euros in the form of additional contributions and taxes paid by firms and employees and reduced public expenditure on unemployment and social benefits (Kuckshinrichs et al., 2011). In Hungary, an *ex ante* assessment of a hypothetical state-funded residential energy efficiency investment programme has estimated that the additional State revenues (VAT, personal income tax and social security contributions) derived from the additional investment and consumption more than compensates the expenses incurred by the State (subsidies and reduced VAT collection from energy savings) (Energia Klub/REKK, 2011).

In addition, the increase in employment rates triggered by the retrofits will help to buffer the pressures on Poland's public pension funds, which are likely to increase in the future because of demographic changes. In a context of constrained government budgets and an ageing Polish population, increasing employment rates arises as one of the few long-term strategies ensuring the sustainability of public pension systems (Hessel, 2003).

Finally, a large-scale retrofit programme will create a broad range of new business opportunities along the supply chain of retrofits, many of them involving local entrepreneurs and located in rural areas. Being a first mover in supplying large-scale deep retrofits may also help developing industries potentially become future exporters of retrofit materials and technologies to the Central and Eastern European region and beyond. This would further enhance Poland's production and employment levels and contribute to reduce its trade balance deficit.

8.4.2 Improved air quality: non-GHG emissions

The combustion of fossil fuels is also responsible for the emission of a large amount of non-GHG air pollutants such as nitrogen oxides (NO_x), sulphates (SO_x), particulate matter (PM) and non-methane organic volatile compounds (NMVOC). This is particularly relevant in the case of Poland, where 44.5% of buildings heat demand is met by coal, which is the most pollutant (and cheapest) energy carrier used in residential and public buildings in Poland. As presented in **Table 8-1** obtained from the 2009 EMEP/EEA air pollutant emission inventory guidebook (EEA, 2009)[8], coal emits almost twice as much NO_x as natural gas and between several hundred and several thousand times more PM_{10} and SO_x than DH or natural gas. Thus it comes as little surprise that in spite of its relatively small size (as compared to other EU economies), Poland is the largest SO_x emitter and the second largest emitter of PM_{10} and $PM_{2.5}$ of the EU (EEA, 2010). In fact, model's results indicate that current heat consumption in buildings is responsible for 43% of Poland's total SO_x emissions and 62% of PM_{10} emissions.

Non-GHG pollutant	Natural gas	DH [natural gas]	DH [hard coal]	DH [brown coal]	Coal
NO_x [g GJ^{-1}]	57	89	310	360	110
SO_x [g GJ^{-1}]	0.5	0.3	820	820	900
PM_{10} [g GJ^{-1}]	0.5	0.9	20	20	404
NMVOC [g GJ^{-1}]	10.5	1.5	1.2	1.7	484

Table 8-1: Emission factors for the three most common energy carriers for space and water heating in Polish buildings

Source: EEA (2009)

A trade-off is thus identified between air pollution reduction and energy security objectives: though the use of coal makes the energy bills of households and public building managers more affordable and reduces the energy dependency of the country, it also results in substantial negative impacts on the public health and ecosystems. This way, SO_x and NO_x emissions have been related ecosystem acidification and eutrophication, PMs are regarded as the dangerous

[8] Default emission factors for natural gas and coal from residential sources. For DH, default emission factors for natural gas-, brown coal-, and hard coal-fired power plants for public electricity and heat production.

pollutant as they penetrate into sensitive parts of the respiratory system, and it is know that high NO_x concentration is a cause of reduced lung function. Tropospheric ozone (O_3) is a secondary pollutant derived from NO_X and NMVOC that can also cause respiratory and cardiovascular health problems and lead to premature mortality. High O_3 levels can also damage plants, which will lead to reduced agricultural crop yields and forest growth. Other compounds, such as the benzo(a)pyrene (BaP), a polycyclic aromatic hydrocarbon which causes cancer in humans, is known to be a problem in areas where domestic coal and wood burning is common such as western Poland, the Czech Republic and Austria (EEA, 2011b). These emissions result in substantial costs to the society in the form of direct welfare loss (i.e., pollution-related morbidity and premature mortality) and additional social security costs (i.e., hospitalization, treatment, working days lost, etc.). That way, a recent study by the European Environment Agency (EEA) has found out that Poland is the EU Member State with the second largest human health and ecosystems damage cost of air pollution (5 to 13 billion Euros per year) from industrial facilities – including power plants – after Germany (EEA, 2011c).

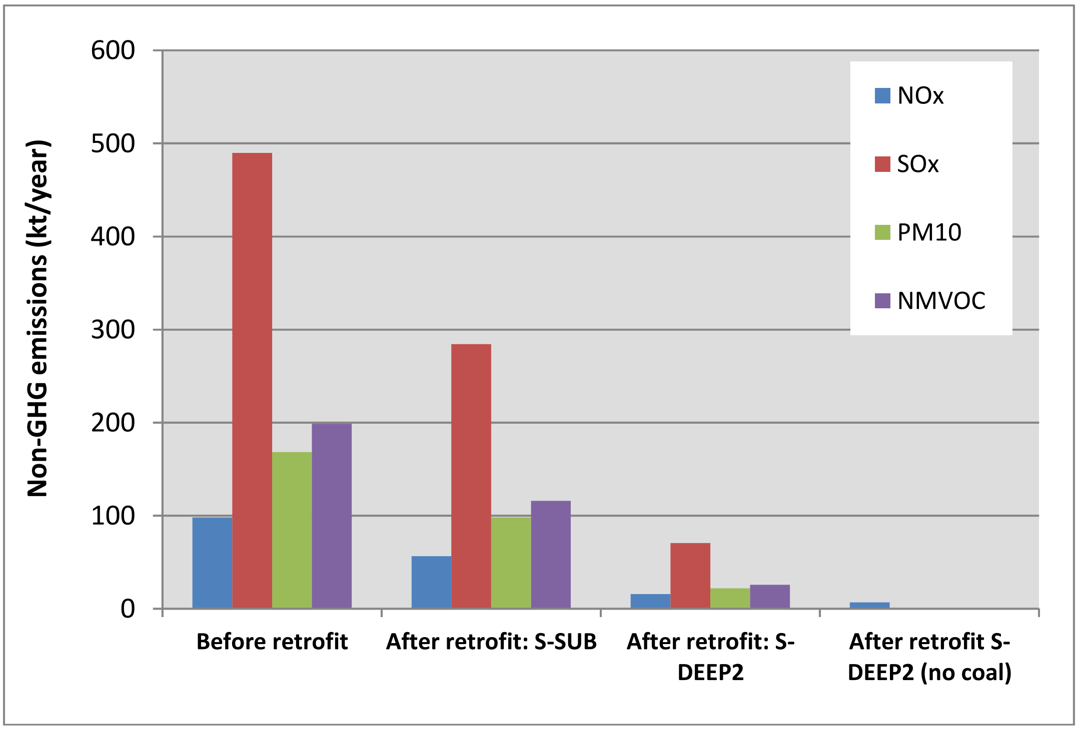

Figure 8-1: Estimated total non-GHG emissions (1000 t per year) of the building sector before and after the retrofit of all buildings (by scenarios)[9]

Source: own elaboration after model results and EEA (2009)

Based on the building model's results and the emission factors presented in **Table 8-1**, total emissions before retrofit and once all buildings are retrofitted have been calculated. It was also

[9] *S-DEEP2* scenario is shown as representative of S-DEEP scenarios.

assumed that DH is provided 25% by natural gas and 75% by coal[10]. The estimates are shown in **Figure 8-1**, which show that the further the reduction in space and water heating requirements, the larger the avoided non-GHG emissions. The figure also incorporates an improved version of the *S-DEEP* scenario in which no coal is used for space and water heating[11]: the results indicate that practically all the buildings-related harmful non-GHG emissions can be eliminated if deep retrofits are implemented along with a progressive substitution of coal by cleaner fuels for the production of heat.

When compared to Poland's total annual emissions (see **Table 8-2**), the model's results indicate that significant reductions can be achieved in these aggregated emission levels. That way, once all buildings are retrofitted to deep levels, 36% and 53% of the country's current total SO_x and PM_{10} emissions respectively can be avoided. If deep retrofits are implemented along with a *phase-out* of coal (substituted by natural gas in these calculations), 43% and 62% of Poland's current total SO_x and PM emissions will be mitigated in the building sector alone (see **Table 8-3**).

Non-GHG pollutant	NO_x	SO_x	PM	NMVOC
Annual total emissions	870.7	1145.7	272.3	693.3

Table 8-2: Poland's annual total emissions of selected non-GHG pollutants (1,000 t per year), as an average for 2006-2008

Source: EEA (2010)

Non-GHG pollutant	Emissions avoided after retrofit (kilotones per year)				Emissions avoided after retrofit (% of Poland's total annual emissions in 2006-2008)			
	NO_x	SO_x	PM	NMVOC	NO_x	SO_x	PM	NMVOC
S-SUB	41.4	205.5	70.2	82.9	5%	18%	26%	12%
S-DEEP2	82.3	419.3	146.5	173.1	9%	37%	54%	25%
S-DEEP2 (no coal)	91.3	489.9	168.4	198.2	10%	43%	62%	29%

Table 8-3: Amount of emissions avoided once all buildings have been retrofitted (all scenarios), in absolute (1,000 t per year) and relative terms (% of Poland's current total annual emissions)

Source: own elaboration after model results and EEA (2010)

In conclusion, deep retrofitting the Polish building stock would largely reduce the amount of coal – and other energy carriers used – for space heating in buildings. A large reduction of non-GHG emissions would follow, which would have substantial positive effects on human health and the environment. Further decreases in pollutants' emissions can be expected if, unlike assumed by the model to avoid further complexity, the increase in the energy efficiency of Polish buildings runs in parallel to a substitution of coal by cleaner fuels.

[10] Rough estimate based on Urząd Regulacji Energetyki (2011): the fuel mix of DH in Poland in 2010 is: 76% coal and 24% of other fuels (fuel oil, gas, biomass and other).
[11] The calculations assume that all coal directly burnt in buildings is substituted by natural gas and that only gas-fired DH power plants operate.

8.4.3 Energy poverty alleviation

As presented in **Section 2.1**, energy poverty is a distinct challenge of today's Poland very closely related to the energy performance of its residential stock: more than one fifth of the Polish population declared to be unable to afford to keep their home adequately warm during the cold season as an average for 2005-2010, and in the same period, nearly 17% the population stated to be in arrears on utility bills. These figures are well above the EU27 average and indicate that a large fraction of Poland's households struggles to cover their domestic energy needs, which results in dwellings heated to substandard levels, a higher incidence mental and physical diseases and in energy poverty-related excess winter mortality.

It is thus clear that a programme that aims at largely improving the energy efficiency of Polish buildings would have positive consequences in terms of fuel poverty alleviation. Obviously, this benefit is only relevant for the residential stock.

It has been argued that "the most sustainable way to eradicate fuel poverty is to *fuel-poverty* proof the housing stock, which means that a dwelling will be sufficiently energy efficient that regardless of who occupies the property , there is a low probability that they will be in fuel poverty" (DTI, 2006, p. 31). Thus, while a suboptimal renovation of Polish dwellings such as the one proposed in the *S-SUB* scenario would reduce to a certain extent the number of households living in fuel poverty, the full completion of any of the *S-DEEP* scenarios would possibly eliminate fuel poverty in the long-term.

Various positive welfare effects would derive from this. Formerly fuel-poor households would enjoy comfortably heated dwellings and lower energy bills, avoid arrears and indebtedness with supplying companies or end using lower-quality, cheaper energy carriers such as firewood coal. In addition, the bulk of Poland's fuel poverty-related excess winter mortality – up to nearly 6,000 excess winter deaths[12], an amount similar to the annual number of Poland's road traffic accidents casualties – could be avoided. This is in the same range as the number of annual deaths from traffic accidents and suicide (see **Figure 8-2**). Most of these premature excess winter deaths occur among the elderly (60 years or more).

As there is also evidence of the mental health impacts of fuel poverty on senior, adult and adolescent populations and on the physical health impacts on children and infants (Liddell and Morris, 2010), additional health benefits would derive from the intervention as well. These aspects are relevant also from a State budget perspective because a healthier population also means less pressure on the public healthcare systems, whose costs are expected to grow in the

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12 Excess winter mortality data reported in WHO (2004) indicate an average of 14,680 excess winter deaths (EWD) per year in Poland for the period 1991-2002. Studies in Europe indicate that between 10% to 40% of the total EWD can be related to fuel poverty (Clinch and Healy, 1999; Buzar, 2007; Friends of the Earth & the Marmot Review Team, 2011; Hills, 2011). Thus, a preliminary estimate indicates that between 1,500 and 6,000 premature deaths could be avoided if fuel poverty were completely eradicated in Poland.

future along with the proportion of elders in the total population. This way, a study in the UK has estimated that the current excess cold hazard costs of energy inefficient homes (F- and G-rated) to the National Health System (NHS) amounts to € 225 million (£192 million) per year (BRE, 2011).

In addition, the UK experience has also indicated the spatial overlapping between fuel poverty and high unemployment, which implies that a programme acting of fuel-poverty affected areas will benefit fuel-poor households also by providing income-earning opportunities (EST, 2000).

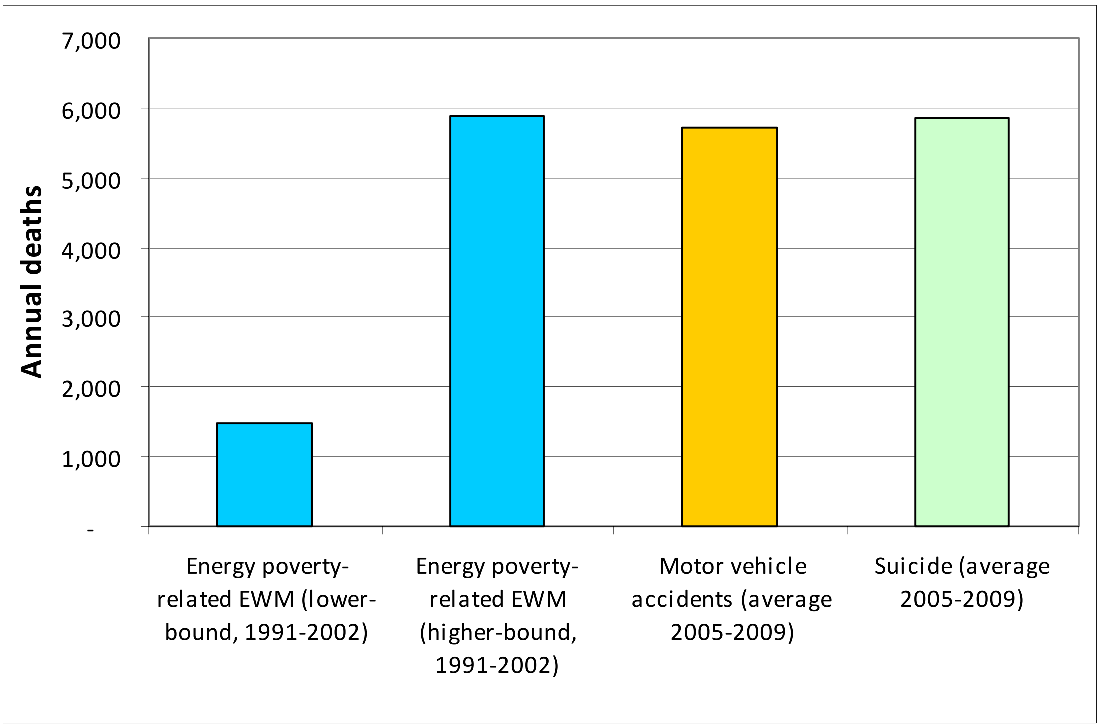

Figure 8-2: Comparison of energy poverty-related excess winter mortality (EWM) and mortality caused by motor vehicle accidents

Source: own elaboration after data from the GUS Local Data Bank and WHO (2004)

However, in order to fully realise the fuel poverty alleviation potential of the programme, certain aspects of the financing scheme would be important. If fuel poor households only got back, as set by the model, a 20% of the achieved energy savings for as long as it is needed to repay the initial investment, its situation would have improved only marginally. Tailored financing tools for low-income households would thus be needed for making the intervention also useful for reducing fuel poverty rates.

8.4.4 Increased rental and resale price of properties

Compared to similar units with the same location and physical attributes, retrofitted buildings have a number of advantages that make them more attractive to buyers of the housing rental and sale markets. In theory, consumers are willing to pay an additional amount of money equivalent to the net present value of the benefits obtained for living in a house with lower utility expenses, better indoor air quality, less outdoor noise infiltration, improved safety conditions, lower maintenance costs, etc.

Typically, the effect of energy efficiency improvements in real estate prices has been analysed through hedonic pricing techniques. With this methodology, a study from Switzerland valued the presence of energy efficient windows at 2-3.5% of the selling price of existing single-family houses (Borsani and Salvani, 2003, in Jakob, 2006). A more relevant analysis of the Dutch housing sector, where an early, voluntary adoption of the EU EPBD energy labeling system is in place, found out that certified properties (A, B or C certificate) were sold with a 2.8% higher transaction price than non-certified. Other equally important findings of this study are (Brounen and Kok, 2010):

- The price premium is proportional with the energy performance of the property. A-labelled homes (similar to the ones that result of the implementation of deep retrofits) obtained a 12.1% price premium in transaction prices as compared to similar G-labeled homes. On the contrary, F-labeled properties only received a 1.7% premium as compared to G-labelled homes.

- In general, the variation price premium is equivalent to the present value of the energy savings that result from a higher energy efficiency level. However, For A-labeled properties, the premium is higher than the capitalized value of the energy savings, which may indicate that other attributes of the dwelling (e.g., better indoor air quality or protection against external noise) are also incorporated in the transaction price of high energy efficiency homes.

That the price of the building as an asset – in fact, it is often the most valuable asset of the households – increases as a result of the intervention is important because it provides an additional financial incentive for households to participate in the programme and for maintaining the energy efficiency gains achieved with the renovation: they will not be only saving money but will also be able to sell or rent their property at a better price because the new owners/tenants expect their household energy costs to be lower than in a conventional dwelling. Actually, enhanced ability to rent or re-sell the property has been defined as one of the co-benefits of buildings' energy efficiency.

Lastly, a deep renovation is also expected to extend the lifetime of buildings. In the case of panel houses, Zavadskas et al. (2008) argue that thermal retrofitting also allows reducing considerably maintenance costs and the cost of future repairs and replacement of worn-out materials.

8.5 Financing[13]

As this study has demonstrated, the energy efficiency ambitions set forth in the *S-DEEP* scenarios result in cumulative net benefits in the long-term and net employment growth over time. Yet despite the financial savings associated with it, energy efficiency will not occur on a wide scale without upfront investment and policies and programs that eliminate financial and practical barriers to EE. As described in **Section 5.2.4**, this study assumes financing via a *pay-as-you-save* scheme that returns 20% of the energy savings to households or public building managers, with the remaining 80% allocated to re-pay the upfront costs over a number of years. The State is assumed to provide an interest-free loan that allows property owners or managers to repay only the principal of the loan over its lifetime.

While the model incorporates this assumption, this study does not aim to define a financing scheme for the building renovation programme. However, this is an issue that any serious attempt to apply the programme must take into consideration. In this regard, it is particularly important to acknowledge that, even discounting the fact that the return on investment of an energy-efficient renovation takes several years, a large fraction of Poland's households may not dispose of sufficient up-front capital to invest in a deep retrofit of their house.

A range of financing mechanisms is available to support a widescale deep retrofit programme – allocations from the general consumption budget, resources obtained from a loan, grants or private savings, etc. (Jeeninga et al., 1999). A conventional energy efficiency programme probably require a public-private financing arrangement, which may be on the order of about one-fourth public, three-fourths private investment (Cowart, 2011), though a deep retrofit program will require an even greater share of public investment. This ratio will change depending on the end-use customer. For example, low-income individuals will require significantly more public support than other groups. Public funding, however, need not flow directly out of the treasury. Rather, it can originate from a number of sources such as EU funds, the carbon markets, energy saving obligations or redirecting of fossil fuel subsidy schemes. Moreover, the funds currently spent on the Thermo-modernization programme, to be substituted by the new renovation programme, would be also available (in fact, what this study argues is the Thermo-modernization programme to be upgraded to a more ambitious initiative delivering much more energy efficient retrofits).

Funding energy efficiency through sources such as these is particularly important as it can assuage concerns that a retrofit programme will exert additional pressure on already constrained national, regional and local budgets. The following sub-sections provide a brief introduction to these mechanisms.

[13] This section has greatly benefited from the input of Edith Pike-Biegunska (The Regulatory Assistance Project, RAP).

8.5.1 Pay-as-you-save (PAYS)

A PAYS scheme, as defined by the UK Green Building Council (UKGBC, 2009), is a scheme whereby the upfront costs of a refurbishment are financed by a third party, which lends the money. An obligation to repay is linked to the property over an extended number of years and the repayments are calculated to be less than the energy savings obtained. Importantly, the obligation to pay, along with the benefits, carry over to new owners under a change of tenure. The obligation to repay can be to the energy supplier or to another third party (DECC and Energy Saving Trust, 2011). A pay-as-you-save scheme would be a feasible option for the proposed intervention in Poland. It would allow for upfront financing, at low or no interest, with a long-enough payback period that customers could realize the benefits of the savings from day one[14].

8.5.2 Reallocation of EU funds

One option for securing public funds to support a retrofit programme, whether under PAYS or another scheme, would be redirecting already planned and future EU funds for financing the energy efficiency scheme. As reported by Stefanova and Konecny (2008), Poland is the CEE Member State with the largest allocation of EU Structural and Cohesion funds for the period 2007-2013 (approximately 60 billion Euros of 2004) but is also the Member State with the smallest allocation of Cohesion and Structural Funds to renewables and energy efficiency (1.4%) after Hungary (1.1%). From this percentage, less than half is being spent on energy efficiency. This contrasts with other CEE nations like Lithuania, which has devoted 5.4% of its Cohesion and Structural Funds to climate investments, mostly energy efficiency. The comparison suggests that there is room for a different use of EU funds in Poland in future budgeting periods without moving too far away from the ranges set by neighbouring CEE Member States. For instance, assuming that the amount of EU funds received by Poland after 2013 remains stable, increasing the allocation of EU funds to energy efficiency to 5% (from the current less than 1%) would make available some 500 million Euros per year that could be used by the government for supporting the retrofit programme.

Poland could also attempt to secure specific EU financing for the large-scale retrofitting programme additional to the national allocations of the various (Cohesion, Structural, etc.) funds from which Poland is already benefiting.

[14] Another programme design that allows customers to pay back EE investments over a long time horizon is a property assessed clean energy (PACE) programme, whereby the obligation is attached to the property taxes. As with PACE, the obligation to pay along with the benefits run with the home under a change of tenure. This programme design has gained significant traction in the United States. For more on PACE, *see* http://www1.eere.energy.gov/wip/solutioncenter/financialproducts/pace.html.

8.5.3 Re-directing subsidies

Another option would be making use of existing subsidies that either provide incentives for energy consumption or enhance the financial profitability of carbon-intensive options. This may be for instance the case of the subsidies to the otherwise declining coal-mining sector, which in the case of Poland amounted to US$$_{2005}$ 9.3 billion for the period 1990-2006 – equivalent to an average of 440 million EUR per year – as estimated by Suwala (2011). However, there are few incentives for a budget reallocation of this type in the current EU context: in late 2010 the European Commission accepted Germany's proposal to extend the phasing out of coal subsidies until 2018 (Reuters, 2010).

Together with a wiser use of available EU funds, redirecting the current subsidies to carbon-intensive sectors (i.e., coal mining) could potentially make available nearly 1 billion Euros per year, an amount that by itself may cover between 25% to 75% of the full annual costs of renovating Polish buildings at a rate of 195,000 units per year (*S-DEEP1* scenario).

8.5.4 Carbon market revenues

The carbon markets offer another potential source of funding and support for building retrofit projects. In particular, from 2013 Poland will have a new source of carbon revenues, flowing from mandatory ETS allowance auctions, that can be used to support energy efficiency.[15] International experience has shown that directing carbon revenues to energy efficiency significantly benefits consumers through reduced bills, lower wholesale electricity prices, and by reducing the cost of meeting carbon goals. In fact, a recent analysis conducted by the Regulatory Assistance Project (RAP) finds that investing carbon revenues in energy efficiency can save 7 to 9 times the energy and carbon emissions than simply relying on the ETS price signal alone.

To understand the benefits of investing carbon auction revenues in energy efficiency programs, it is useful to look at the example of the Regional Greenhouse Gas Initiative (RGGI) in the United States. RGGI is a cap-and-trade program for CO_2 in the electric sector, covering ten Northeastern States, with a population of roughly 50 million and accounting for roughly 19% of the US economy. 90% of RGGI proceeds have been auctioned over the three years since the program began, amounting to $912 million. 48% of those proceeds have been allocated to energy efficiency programs, with some states investing over 80% of proceeds in energy efficiency. Over three years, consumers have experienced a net gain of nearly $1.1 billion, taking into account the reduction in energy bills over time. RGGI has generated 16,000 job years in the midst of an economic recession, and reduced payments to out-of-region providers of fossil fuels by just over $765 million (Hibbard et al., 2011; Chang et al., 2010).

[15] The exact amount of carbon revenues that Poland will generate will depend on a number of factors, chiefly: the proportion of allowances auctioned and the carbon price. While current estimates for the carbon price in the 2013-2020 period are low, this could change if Europe were to agree to reduce the volume of allowances in circulation.

8.5.5 Energy company obligations plus wires charge

An energy company obligation (ECO) is a mechanism for both implementing and financing energy efficiency programmes. Under an ECO, energy distributors or suppliers are charged with achieving a certain level of energy savings. Costs can be recovered through a small charge on customer bills. While the charge increases the per kWh charge, bills are reduced due to both direct savings as well as broader system benefits that reduce the market price of energy. The wires charge provides the benefits of a stable, long-term source of funding, while involving energy companies puts responsibility for efficiency on the actors in the sector directly connected to the purchase and sale of energy. Implementation of energy efficiency measures can be carried out by the energy companies, or by third parties.

There are two key elements to ensuring deep retrofits within an ECO. The first is to create objectives that focus on lifetime savings rather than annual savings. This can be done in a number of ways: explicitly, by setting minimum average measure life requirements, giving lower credit to shorter-lived measures, putting limits on the portion of the obligation that can be met through shorter-lived measures, etc. The second is to explicitly state where or how the savings obligation must be met, which is commonly referred to as ring-fencing. The experience in jurisdictions where requirements for whole house retrofits have been included within a supplier obligation – such as the UK's CERT (Carbon Emissions Reduction Target) programme, Ireland's Better Energy programme or Ontario's gas demand-side management regulatory policy guidelines – provides relevant examples in this regard.

Poland's new white certificate scheme is an ESO that obliges energy suppliers to reduce energy use by a set amount annually, and allows third parties to participate in the programme by bidding their energy efficiency measures into an auction that determines which projects will be eligible to generate white certificates. While the scheme is a step in the right direction, it is difficult for deep building retrofit measures to compete with less expensive energy efficiency measures that represent lower-hanging fruit. Moreover, the ESO only lasts until 2016, too short a period of time to create the long-term, stable signal needed to develop a robust market. By extending the programme and placing a special focus on deep renovations and long-term savings, it would be possible to expand Poland's ESO to support deep renovations, thereby avoiding the lock-in of the energy saving potential and creating robust savings over time.

8.5.6 Sale of CO_2 quota

Another potential source of capital for financing energy efficiency retrofits is the sale of CO_2 quota allocated under the Kyoto Protocol (i.e., excess Assigned Amount Units or AAUs). However, their future is uncertain both within Europe and within the international framework as the future of an international agreement is not clear.

That said, a somewhat analogous mechanism to the excess AAUs is the surplus of AEAs (Annual Emission Allocations) Poland is expected to receive for non-ETS emissions under the Effort Sharing Decision in an EU context. Poland's economy is expected to grow, and so Poland is expected to need most if not all of its AEAs in order to cover the increased emissions associated with economic growth. But, if Poland were to invest in energy efficiency measures, it may have excess AEAs to sell.[16] Since the Effort Sharing Decision authorizes Member States to transfer a portion of their annual allocation to other Member States (Effort Sharing Decision, Article 3.4 and 3.5), the transaction would be analogous to transfers of AAUs under the Kyoto Protocol. The GIS (green investment scheme) model employed for the sale of AAUs under the Kyoto Protocol could, potentially, be employed for sales of AEAs as well.

Another mechanism that could support building retrofits in Poland is domestic offsets under Article 24a of the ETS Directive. As the Regulatory Assistance Project (RAP) proposes, domestic offsets can help compliance entities under the ETS meet their emissions targets at lower overall cost by crediting low-cost emissions reductions in non-ETS sectors, thereby supporting a low-cost path to achieving Europe's climate goals while creating an investment stream for modernization and emissions reductions in non-ETS sectors.

8.5.7 Overcoming additional barriers

While financing is indispensable to pay the upfront costs of a deep retrofit programme, it addresses just one of the several barriers to energy efficiency – that of upfront capital costs. In fact, a combination of both financing and rebates are needed to roll out a deep retrofit programme (RAP, 2011). Moreover, there are a number of other barriers that must be addressed such as split incentives and information barriers. Lastly, it is important that a deep retrofit strategy address expand private sector supply-chain capacity, minimizes confusion in the market (i.e. simplifies messaging and branding), and that there is a strong and stable government commitment to implementing a deep retrofit programme (RAP, 2011).

8.6 Applicability of the results to other Member States

Building upon the experience from the previous study in Hungary (Ürge-Vorsatz et al., 2010), this research contributes to alleviate the scarcity of studies exploring the social and economic impacts of improving the energy efficiency of buildings in Central and Eastern Europe. By forecasting the impacts on energy consumption, emission and employment levels of deep retrofitting Poland's buildings, this research series incorporates the largest Member State of the CEE region.

CEE countries share with Hungary and Poland common features such as energy prices on the rise (though still below EU averages), energy inefficient building stocks, relatively low incomes if

[16] Other countries stand to have excess AEAs to sell as well. For example, Hungary is expected to have a surplus that would rise if Europe were to set a 30% GHG reduction goal for 2020 (REKK, 2011)...

compared to Western European standards, constrained government and household budgets, and employment rates to be improved. They are thus facing similar energy, employment, climate and fuel poverty challenges, but also have similar potentials to improve the energy performance of their building stock and thus to lower the burden of energy bills on the households' budget and to largely reduce their energy imports and GHG and non-GHG emissions.

Though the conditions of the labour markets and the building stock vary from country to country, the comparison between the results of the Hungarian and Polish study (see **Figure 7-14**) indicates that substantial positive energy saving, carbon emission reduction and employment net employment effects are to be obtained from an intervention like the one suggested in this study. In fact, as long as certain key assumptions hold – e.g., an inefficient building stock relying on fossil-fuels for heating, increasing energy prices, labour intensity of building renovation activities above the labour intensity of the energy sector – similar positive employment and climate effects will be obtained from the application of the combined case study-I/O methodology used in this research series. Furthermore, in the case of Poland, substantial public health and ecosystems' protection benefits will be also attained as a result of the reduction in the emissions of non-GHG pollutants derived from the combustion of coal in buildings.

9 Conclusions, recommendations and further research needs

9.1 Summary of the findings

The research presented in this report confirms the high potentiality for energy savings, carbon emission reduction and net additional employment creation of Poland's public and residential building stock. Currently this potential is being captured only to a limited extent by the Thermo-modernisation programme, which since the late 1990s has retrofitted 20% of the Polish building stock achieving an average level of energy savings of 30% of the building's previous energy consumption. Even though this is probably more than what has been achieved by other CEE nations in the same period, there is a risk that, if further implemented under the same conditions, the Thermo-modernisation programme will *lock-in* a large fraction of that potential. Thus a main aim of this study is to show the additional energy saving, carbon emission reduction and employment creation benefits of upgrading the Thermo-modernisation programme to deep energy efficiency levels.

Two sets of results have been consequently obtained. A first set (**Section 6**) corresponds to the energy savings (for space and water heating) and avoided GHG emissions achieved by the implementation of the base, suboptimal and deep renovation technologies. Though treated as an intermediate output of the model, they are also relevant results because reducing energy consumption and emissions are a primary target and benefit of a buildings' energy efficiency programme. Based on those, the direct, indirect and induced net employment effects created by each of the scenarios have been then estimated (**Section** 7). To the knowledge of the research team, no previous estimate of the net job creation of a nationwide buildings renovation programme in this country has been produced.

The results presented in **Section** 6 show that, if fully implemented, the *S-BASE* scenario – i.e., the *business-as-usual* continuation of Poland's Thermo-modernisation programme – will reduce the total energy consumption of Polish buildings from 190 to 142 TWh per year in a period of 33 years and at an annual investment cost of roughly 1 billion Euros. The *S-SUB* scenario (an improved version of the retrofitting programme achieving 50% of energy savings) would decrease the buildings' energy consumption to 110 TWh per year (42% reduction) in a period of 33 years at an annual investment cost of some 2.2 billion Euros. And *S-DEEP* scenarios would bring the aggregated energy consumption down to just 30 TWh per year in 68 years (*S-DEEP1*), 42 years (*S-DEEP2*) and 31 years (*S-DEEP3*). The annual investment costs of deep renovations change as the specific costs per sqm. are assumed to decrease gradually throughout the implementation period. They peak at approximately 3 billion Euros (*S-DEEP1*), 6 billion Euros (*S-DEEP2*) and 8 billion Euros(*S-DEEP3*) per year in 2016.

These results prove that, no matter the speed of implementation, the three *S-DEEP* scenarios deliver very substantial reductions in the energy used and carbon emitted by the Polish building stock: up to 84% of Poland's buildings current space and water heating energy use, and the corresponding CO_2 emissions, can be avoided by a consistent and wide-spread deep retrofit of the country's public and residential buildings. *S-BASE* and *S-SUB* scenarios would reduce total energy consumption by 25% and 42% respectively. Thus if base or suboptimal renovations were implemented instead of deep retrofits, between 60% and 43% of the estimated energy saving potential of the Polish building stock would have been *locked-in* at the end of the implementation period.

The reductions in carbon emissions are of the same magnitude as the energy savings obtained for the different scenarios, and highlight the *lock-in* risk that the implementation of less ambitious renovation programmes entails. Reaching ambitious mid-term climate targets, such as the IPCC's proposal to reduce 50 % to 85% of the year 2000 emissions by 2050, will become extremely difficult, and expensive, to achieve, if suboptimal or *business-as-usual* solutions are applied.

Because of the relative inexperience with deep renovation know-how and technologies, these will initially be more expensive than after a learning period when experience accumulates and more mature markets and competitive supply chains are established – the so-called *learning factor*. Therefore, from a total cost perspective a more gradual implementation of a deep renovation program is more attractive. A more aggressive implementation rate (i.e., equivalent to 450 thousand dwellings renovated per year, as proposed in scenario *S-DEEP3*) would result in higher overall costs (undiscounted): 164 billion Euros by 2080. The full implementation of *S-DEEP1* and *S-DEEP2* would result in a lower amount of 146 and 124 billion Euros by 2080 respectively. These costs can be shared by building owners, the government and even utility companies, with additional sources of capital like the sale of CO_2 quota and revenues from EU ETS auctions, helping to meet the financing needs of the program (see financing options in **Section 8.5**). Besides, a careful implementation can minimize total costs, i.e., building types with a lower cost per sqm. (e.g., multi-family units built in 1945-1970) can be retrofitted first and then proceed with more expensive typologies (e.g., single-family units from 1971-1988) at later stages, once the learning factor has effectively reduced the cost of retrofits.

On the other hand, the faster the retrofits are implemented, the faster will energy saving benefits be harvested: on the benefits' side, a more ambitious implementation rate results in a faster harvesting of energy saving benefits: by 2080, the total accumulated undiscounted net benefits of *S-DEEP3* amount to 203 billion Euros, whereas *S-DEEP2* and *S-DEEP1* generate 186 and 122 billion Euros each (see Section **6.5**). All in all, these results indicate that in the long-term, the energy saving benefits accrued through retrofits surpass investment costs, and that deep retrofits are preferable to suboptimal from an undiscounted private costs vs. benefits perspective. Among deep scenarios, a more ambitious retrofit rate delivers more undiscounted net benefits and is a preferable alternative as long as the potential negative effects described in **Sections 7.3.27.3.3** and **9.2.2** (e.g., destruction of the previously created employment because of the learning factor, bottlenecks in the supply of labour, capital and materials) are dealt with. Because of the existing trade-offs, *S-DEEP2* scenario can be suggested as a rate of retrofit that maximizes net benefits without compromising the feasibility of the programme or creating imbalances in the labour and other markets affected by the retrofits.

A careful of review of these economic results, which are less appealing than the ones obtained for the preceding Hungarian study (Urge-Vorsatz et al., 2010), concluded that that among all the model parameters the main difference has to do the with the fuel mix: most Polish buildings use coal (either directly or as district heating), a cheaper fuel than natural gas, for heating. This is the key factor which makes deep retrofits look relatively less attractive than suboptimal ones in Poland. If Poland had substituted coal as a heat source by natural gas (as Hungary did in the 1990s), net economic benefits would be achieved much earlier (before 2050). This conclusion, obtained as a *by-product* of the comparison of both studies, indicates that a coal-based economy is less likely to adopt energy efficiency measures because it has fewer incentives to do so.

When compared to alternative mitigation strategies, building retrofits are a more cost-effective solution. If the amount of carbon emissions avoided by retrofit scenarios until 2080 were to be mitigated in power plants through CCS (carbon capture and storage, a relevant alternative mitigation option according to Poland's energy strategy), this would result in significant net costs, whereas building retrofits deliver substantial net benefits. It must also be noted that CCS – unlike energy efficiency retrofits – increases the production cost of coal-based electricity between 20 to 90% and does not bring as many co-benefits (see **Section 6.6**).

In addition to private energy saving benefits, social external benefits such as the positive impacts of avoided emissions need to be accounted for as well. These refer to the increased welfare of reduced climate change and of the avoided impacts on human health and on ecosystems caused by non-GHG pollutants ($NO_{x,}$ SO_x, PM and NMVOC). The results of the study have demonstrated that deep retrofitting the Polish building stock is a powerful tool to reduce the latter. When all buildings have been retrofitted, 84% of the estimated 2010 total non-GHG emissions associated with energy use in the building sector can be avoided. If retrofits are complemented by a *phase-out* of coal (i.e., assumed to be substituted by natural gas), this would lead to nearly zero non-GHG emission levels, which means avoiding 43% and 62% of Poland's total (i.e., building and non-building related) current SO_x and PM_{10} (see **Section 6.7**)

The economic value of the total avoided emissions has been estimated through the avoided external cost of CO_2 and non-GHG pollutants, which were retrieved from IPCC's 4th Assessment Report and the EU's *NewExt* project. The model results prove that the social benefits of avoided emissions are larger than the energy saving benefits in the short, middle and long-term.

With regard to the employment effects, as expected *S-DEEP* scenarios report larger net employment gains than *S-BASE* and *S-SUB* scenarios because of the higher costs per unit of deep retrofits (higher retrofit costs imply higher labour demand). At the beginning of the implementation period (2011), the *S-BASE* scenario generates a net amount of 50 thousand FTE per year, which decreases progressively until the 15 thousand FTE level by 2030. The *S-SUB* scenario produces around 95 thousand FTE per year in 2016 (at the end of the ramp-up period), which decrease until around 40 thousand FTE per year in 2030. Finally, the annual net employment impacts of *S-DEEP* scenarios are different because of the evolution of energy prices and renovation costs per sqm: for the period 2016-2030, they range between approximately 390 and 100 thousand FTE per year (*S-DEEP3*), 280 and 70 thousand FTE per year (*S-DEEP2*) and 170 and 40 thousand FTE per year (*S-DEEP1*). From the perspective of the stability of the employment created, lower implementation rates (i.e., scenario *S-DEEP1*) are desirable because it reports a less aggressive reduction in the amount of FTE per year as estimated by the model (see **Section 7**).

By 2020, the study has demonstrated that a large-scale, deep renovation programme in Poland could create over 250 thousand net additional jobs per year, as opposed to the approximately 40 thousand in the suboptimal scenario. These figures include the workforce losses derived from the permanent energy savings achieved (direct employment losses in the energy supply sector and other supply-chain related sectors) and discount the amount of *business-as-usual jobs* (40 thousand FTE per year) that the baseline scenario is currently providing.

It is important to highlight that many of the positive employment impacts are due to the indirect and induced impacts of renovation activities (i.e., in the sectors supplying materials and other inputs to the construction sector, plus in all other sectors of the Polish economy positively impacted by the programmes): in 2020, 75% to 80% (depending on the scenarios) of the gross positive employment created corresponds to these categories, whereas 20% to 25% of those jobs are created in the construction sector. By skill levels, most of the direct jobs created in the construction sector are in the skilled (manual) workers category in both *S-SUB* and *S-SDEEP* scenarios

The mind-term decline in the net amount of jobs forecasted by the model is substantial – after 2040, negative net employment effects are expected. This decrease is due to the direct, indirect and induced negative employment effects related to the energy savings (for all scenarios) and also to the reduction in the per unit renovation costs that is expected to happen only in *S-DEEP* scenarios. Most of those job losses occur as indirect and induced effects (in 2020, around 80% of the gross negative employment effects are foreseen in these categories in all scenarios). It is worth noting that not very significant job losses (up to a maximum of 6% of gross job losses in 2020, depending on scenarios) occur in the mining and quarrying sector. This is a particularly sensitive sector for Poland in terms of its employment losses, as proven by the resistance of organised labour unions to mine closures during the transition period (Suwala, 2011).

Per unit of investment, *S-DEEP* scenarios are estimated to generate 42 net FTE per million Euros in 2020, whereas *S-BASE* and *S-SUB* report 36 and 39 FTE per million Euros respectively (these figures are expected to be reduced as net employment impacts decrease until becoming negative after 2040). For *S-DEEP* scenarios, they are a bit higher than those estimated in the Hungarian study (Ürge-Vorsatz et al., 2010) and above the average recorded for similar projects in Europe and the USA (see **Section 7.5**).

The net job creation results are sensitive to assumptions in a number of key parameters. *S-DEEP* scenario results seem to be particularly responsive to variations in the initial renovation costs and in the learning-factor based decrease of renovation costs per sqm. In addition, the model forecasts that the employments created are at least mid-term (until 2040), though a substantial reduction in the number of net jobs created by the programme is expected as a result of the energy savings and the learning factor. The fact that the whole building stock is considered for renovation implies that the new jobs are likely to be distributed throughout the country as renovations are usually carried out by local small and medium enterprises. The availability of labour to satisfy the additional workers demand generated by the programme seems to be guaranteed by the existing unemployed and inactive workforce of the country.

Building retrofits are a long-term solution to fuel poverty too. This is a significant problem in Poland, where 22% of the population (8.6 million people) declare to be unable to afford to keep their home adequately warm during the cold season and 17% the population (6.4 million people) state to be in arrears on utility bills. These results in dwellings heated to substandard levels, a higher incidence of mental and physical diseases, financial imbalances for utility companies, energy poverty-related excess winter mortality. For the latter, some initial calculations indicate that up to nearly 6,000 excess winter deaths – an amount comparable to the annual number deaths from road traffic accidents or suicide – can be avoided yearly by ensuring sufficient indoor thermal comfort levels of Polish dwellings (see **Section 8.4.3)**.

Energy efficiency investments are also expected to have positive fiscal impacts in the form of reduced government expenditures (e.g., unemployment benefits, social welfare payments and energy costs of public buildings) and enhanced government revenues (additional tax collection), though a certain decrease in revenues associated with lower energy consumption also has to be accounted for. Though evidence is still scarce, a recent study of the fiscal effects of energy efficiency investments in Germany has found out that for each euro invested public authorities get back 4 to 5 euros in the form of additional contributions and taxes paid by firms and employees and reduced public expenditure on unemployment and social benefits (Kuckshinrichs et al., 2011).

A large-scale retrofit programme will also create a broad range of new business opportunities along the supply chain of retrofits, many of them involving local entrepreneurs and located in rural areas. Being a first mover in supplying large-scale deep retrofits may also help developing industries potentially become future exporters of retrofit materials and technologies to the Central and Eastern European region and beyond. This would further enhance Poland's production and employment levels and contribute to reduce its trade balance deficit (see Section **8.4.1**)

Retrofitted properties will also have higher rental rental and resale prices in real estate markets. That way, the study has located a hedonic price analysis of the Dutch housing sector that recently found out that A-labelled homes (similar to the ones that result of the implementation of deep retrofits) obtained a 12.1% price premium in transaction prices as compared to similar G-labeled homes (Brounen and Kok, 2010). This co-benefit, which is reaped privately by the owners of the property, is key to ensure the adoption of the measure by households for maintaining in the long-term the energy efficiency gains achieved with the retrofits (see **Section 8.4.4**).

Finally, other related positive effects are the reduction in imported natural gas dependency (see **Section 6.2**). Even though natural gas only supplies 8.2% of the heat consumed by the country's building stock, a large fraction of it (69%) is imported. Thus by 2030, natural gas savings would range from 21% (*S-BASE*) to 77% (*S-DEEP3*) of the average amount of natural gas imported to Poland in the 2006-2009 period.

In conclusion, the results clearly indicate that adopting a high efficiency retrofitting standard close to passive house (reducing on an 84% of the energy consumption for space wan water heating, such as presented in *S-DEEP* scenarios) would result in a substantially higher number of employments, larger energy savings and carbon reductions and more co-benefits than the *business-as-usual* (continued implementation of the Thermo-modernization programme achieving a 30% reduction in energy use, *S-BASE* scenario) and sub-optimal renovation (improved scenario achieving 50% of energy savings in refurbished buildings, *S-SUB* scenario) alternatives.

9.2 Recommendations for the implementation of a large-scale residential energy efficiency programme

9.2.1 Key recommendations

This research offers decision-makers three alternatives for improving the energy efficiency of Poland's public and residential buildings. The first two options consists in keeping on implementing the currently existing State-supported Thermo-modernization programme (*S-BASE* scenario) or applying an improved programme aiming at 50% energy savings (*S-SUB* scenario). This entails lower renovation costs, but also smaller employment effects and lesser energy savings (25% and 42% of the current energy use for space and water heating respectively) and avoided GHG and non-GHG emissions. They also *lock-in* a substantial fraction of the energy savings and mitigation potential of the building stock. The third option (*S-DEEP* scenarios) suggests the application of state-of-the-art know-how based in the passive house concept in order to realise the full potential of Polish buildings. It greatly reduces the energy consumption of buildings (84% of the current energy use) and creates many more additional jobs, but does it at the expense of higher costs. The annual investment needs of deep scenarios are significant, accounting for several percentage points of the Polish government budget: in the peak year, they amount to up to 8.4 billion Euros per year (*S-DEEP3*), 6 billion per year (*S-DEEP2*) and 3.6 billion per year (*S-DEEP1*)..

Even with deep retrofits looking like the most recommendable option, decision-makers face the following dilemma: higher energy efficiency gains imply larger net employment effects and larger energy and carbon savings, but also a heavier burden on the households' and State budget. Though the proposed *pay-as-you-save* financing scheme may help to largely overcome the barrier of deep renovation costs, the programme's viability depends on a careful control of key parameters:

- Since energy savings are the main source for the repayment of the initial investment costs, the evolution of energy prices is fundamental to ensure that the capital costs of the programme are repaid to lenders. This is particularly relevant for the case of Poland, where nearly 45% of the energy consumed in buildings for space and water heating is provided by a cheap and polluting fossil fuel (coal). Given the country's relatively low energy prices in comparison with the EU average, higher energy costs are expected in the mid- to long-term as energy prices become fully cost-reflective, taxes increase and fuel substitution (e.g., coal by natural gas) progresses. Any increase in energy prices beyond the model's assumptions (see **Section** 5.1.9) will surely improve the appeal of deep renovation programmes from a financial perspective (investment costs vs. energy savings), though it would have a temporary negative impact in fuel poverty rates until all buildings have been retrofitted.

- An additional related recommendation would be coupling the implementation of the deep retrofit programme with a policy aimed at bringing to an end the use of coal as a source of heat in buildings (e.g., users of deep-retrofitted units would be forced to meet their remaining energy needs after refurbishment with clean energy carriers such as natural gas or electricity). This is expected to reduce the atmospheric concentration of non-GHG pollutants (NO_x, SO_x, PM and NMVOC) and thus have significant positive effects on the human health and ecosystems of Poland.

- The decrease of deep renovation costs is key for ensuring the long-term financial viability of the deep renovation scenarios. The research assumed a learning-factor based rate of decrease in deep renovation costs in the model (see **Section** 5.1.7). The implementation agency of the proposed deep energy efficiency renovation programme should therefore watch over these costs and ensure that they are reduced as expected.

- To make the programme viable, the government should act on its present structure of budget allocations. Redirecting the current energy-related subsidies (i.e., subsidies to the coal sector) and making a wiser use of available EU funds could provide the financial resources needed for the State's contribution to the financing of the programme (see **Section** 8.5). A combination of both alternatives would likely make available nearly 1 billion Euros per year, an amount that by itself would cover between 25% to 50% of the full annual costs of renovating Polish buildings at a rate of 195,000 units per year (*S-DEEP1* scenario). This source of capital can be complemented with revenues from the mandatory EU ETS allowance auctions from 2013. Additional financing tools identified are pay-as-you-save schemes (PAYS),, energy company obligations and sale of CO_2 quota.

- Having in mind the effects of the learning-factor based decrease of deep renovation costs, it is suggested to start by refurbishing the cheapest units (e.g., multi-family building built in the periods 1945-1970 and 1989-2010 – see **Table 6-2**) and progressively incorporate more expensive building typologies in order to avoid the *lock-in* of financial resources. This would allow the deep renovation industry and market to develop and to reduce costs by learning. With this approach, the most expensive building typologies would be retrofitted by the time the costs per sqm have decreased to a certain extent, though it would also delay part of the energy and carbon savings. Though the model assumes a constant percentage of all building typologies renovated per year, it would be possible to devise an optimal implementation pathway in which the total costs of the programme are minimised.

- The implementation rate (i.e., number of units to be refurbished per year) is a key parameter defining the annual costs of the programme and the evolution of net employment gains throughout the implementation period. Among the three options presented for deep scenarios, a relatively modest goal as the one defined by the *S-DEEP1* scenario (equivalent to 195,000 units per year) is recommended for three reasons. First, it exerts less pressure on the government budget (though extended during a longer period). Second, from the perspective of the stability of the employment created, a slower renovation rate scenario is desirable because it reports a less aggressive reduction in the amount of FTE per year as estimated by the model. And third, a smaller number of renovations is less likely to create shortages in the labour and materials supply. In that same direction, a more extended *ramp-up* period (i.e., a more progressive increase the annual amount of retrofits until reaching the target rate) may also contribute to ease the transition to a full-throttle programme.

9.2.2 Additional aspects of the implementation of the programme

The implementation of a renovation programme such as the one proposed requires the government's involvement and leadership. In particular, the public administration should be decisively involved in the planning (deciding on the target depth of the retrofits, implementation rates, building typologies to be acted on first, etc.), the financing (devising secure, stable and credible financing schemes that make the energy savings pay for the initial investment costs) and in ensuring the quality of the renovation (that the renovation delivers the expected energy savings is key to ensure the financial practicability of the intervention).

In parallel to the improvement of the existing building stock, the government may also pay attention to new buildings in order to avoid imbalances in the purpose of the intervention (i.e., it would not make sense that older buildings were more efficient than the new units). For that, an update in the energy consumption requirements of the existing building code would be needed in order to reach a standard close to passive house. Incorporating the new buildings sector into the programme would probably have additional positive effects in terms of effectively reducing the costs of deep renovations following the learning factor rationale. However, if no public support for new buildings is available, the additional costs of constructing new passive-house buildings will be transferred to buyers, which may distort real estate markets to some extent, and the additional energy efficiency increases would be achieved at a very low cost for the State. There is nevertheless evidence indicating that the difference in the price of business-as-usual and passive-house new constructions is relatively small[17], especially if they are produced at large scale.

Bottlenecks in the supply of key production inputs (i.e., labour and materials) may appear depending on how markets react during after and the first five years of the programme (ramp-up period). If the programme outpaces the rate of increase in labour and materials supply, shortages may result in an increase of prices and costs of renovation. A possible contribution of the government would be creating conditions that avoid shortages in the supply of:

- Labour: this can be done by providing the skills to the future workers involved in the programme, creating incentives for the inactive population to move back to the search of a job, and possibly also by helping laid-off workers in the energy sector (e.g., re-train for working in the construction/renovation industry). The programme thus offers a possibility to bring back a portion of working-age Poles – particularly the so-called discouraged workers – that are not currently part of the active population. A comprehensive strategy encompassing changes in the curricula of university and vocational schools and re-training programmes for skilled and unskilled workers would also be advisable.

- Retrofit materials and equipments: since the size of the deep renovation materials market is practically inexistent, manufacturers may not be able to catch up with the increased demand of the programme. The public administration may then be interested in checking the reaction of the supply (for instance, by tracking the evolution of wages and price of materials) and by fine-tuning the rates of renovation as the programme moves forward. Also, in order to maximise the indirect effects (i.e., supply chain-related) of the programme, the domestic production of construction materials and equipment

[17] For Germany, the *Passiv Haus Institut* has estimated that the cost of constructing a new single-family passive house is 8% higher than the national average (Feist, 2007). Other examples from Norway indicate that the price difference can be even smaller, i.e., 5% (Enova, 2008).

could be promoted as long as national suppliers provide materials of the same quality and at the same or lower prices than imported ones.

On the other hand, by making households (and public building managers) responsible for the repayment of the initial investment costs through their energy savings, the programme would transfer the responsibility of making the renovation to pay by itself to the building owners. That way they have clear incentives to make a proper use of the technology and maintaining in good conditions the renovated units. This may also avoid a substantial part of the rebound effect as households would be interested in not using more energy than needed in their newly renovated dwellings, so that they ensure an easy repayment of the initial investment costs.

To sum up, decision-makers of today's Poland have the possibility to unlock the potential for creating additional jobs while greatly reducing the energy costs of households and public buildings and Poland's gas dependency, and making a key contribution to mitigate climate change at a national level. Between the three options presented, the results indicate that deep (i.e., passive-house type) renovations are recommended as long as the assumptions on the increase on energy prices and the decrease of renovation costs hold. High efficiency renovations create more jobs, save more energy, avoid more energy imports and reduce more GHG and non-GHG emissions.

9.3 Further research needs identified

An additional outcome of this series of studies on the employment effects of deep energy efficiency in buildings of Central and Eastern Europe (Hungary and Poland) is the identification of information and knowledge gaps that further research efforts may want to address:

- A comprehensive analysis of the wider macroeconomic impacts of the intervention using more complex tools such as Computable General Equilibrium Models would be necessary for forecasting changes in total output (GDP), wages of the construction and other sectors, price of material inputs, State revenues, etc. This would allow, for instance, estimating the job losses occurred as a consequence of re-directing energy subsidies and EU funds into the programme, or of the decrease in energy taxes collection.

- This series opens the door for a more detailed analysis of financing tools for deep renovation. This is particularly important as for the time being high efficiency retrofits are proportionately more expensive than sub-optimal. Financing advanced refurbishments for low-income households through *pay-as-you-save* schemes seems to be particularly challenging.

- As discussed in **Section 5**, the research has highlighted the paucity of data on the actual costs, energy savings achieved and actual labour requirements of deep renovations. This is clearly the case of Poland, where no information on deep retrofits could be retrieved.

A systematic compilation of data from completed projects would make possible a more accurate prediction of the costs, energy savings and direct employment effects of any planned renovation.

- Though some co-benefits have been economically assessed (i.e., external benefit avoided GHG and non-GHG emissions), further efforst are needed into this direction in order to estimate the real impact on welfare of building retrofits. For that, the application of more complex economic valuation tools and the comparison of costs and benefits in a cost-benefit analysis framework (see OECD, 2006) are advised.

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ANNEX A

The following table shows the employment impacts of energy efficiency activities, Table 7-2 lists the most important results for studies analyzing the impacts on jobs of renewable energy and other "green" measures, while Table 7-3 gives a few examples of research studying employment impacts for non energy related activities.

Resource	Reference	Year	Location	Intervention	Jobs/M€ invested
EU SAVE Programme	Wade et al., 2000	1995	European Union	Energy Efficiency	26.6
SAVE: UK Case Studies	EST, 2000	1996	United Kingdom	Energy Efficiency in Buildings	82.65
The Size of the U.S. Energy Efficiency Market	Ehrhardt-Martinez and Laitner, 2008	2004	U.S.A.	Energy Efficiency Energy Efficiency in Residential Buildings	6.76 10.08
Green Collar Jobs in the U.S. and Colorado	Bezdek, 2009	2007	U.S.A. and Colorado	USA: Base scenario USA: Moderate scenario USA: Advanced scenario Colorado: Base scenario Colorado: Moderate scenario Colorado: Advanced scenario	10.97 11.21 10.97 13.55 13.96 15.44
Investing in Clean Energy	Pollin, Heintz and Garrett-Peltier, 2009	2009	U.S.A.	Building retrofits Mass transit/freight rail (90% MT, 10% FR) Smart grid	16.60 22.18 12.41
Danish Green Jobs	Juul, Hansen, Hansen and Ege, 2009	2009	Denmark	Energy renovation of poorly insulated housing Energy savings in buildings operated by local authorities Regulations requiring energy savings built into new buildings Average	4.05 16.67 13.57 7.13
Rebuilding America	Hendricks, Goldstein, Detchon and Shickman, 2009	2009	U.S.A.	Building retrofits	17.44
National Association of Home Builders	NAHB, 2009	2009	U.S.A.	Building retrofits	15.34
Center on Wisconsin Strategy	Sundquist, 2009	2009	Wisconsin, U.S.A.	Building retrofits	9.67
CECODHAS Offer to Fight Climate Change	CECODHAS	2009	Europe	Building retrofits	21.25
				Average	17.07

Table A-1: Employment Effects for Energy Efficiency and Building Retrofit Activities

Resource	Reference	Year	Location	Intervention	Jobs/M€ invested
Green Collar Jobs in the U.S. and Colorado	Bezdek, 2009	2007	U.S.A. and Colorado	USA: Base scenario USA: Moderate scenario USA: Advanced scenario Colorado: Base scenario Colorado: Moderate scenario Colorado: Advanced scenario	18.25 18.40 17.93 11.47 10.57 11.83
Green Energy Investments for Ontario	Pollin and Garrett-Peltier, 2009b	2008	Ontario, Canada	Green Energy: Baseline Green Energy: Expanded program	29.50 75.83
Investing in Clean Energy	Pollin, Heintz and Garrett-Peltier, 2009	2009	U.S.A. and Colorado	Oil and natural gas Coal Wind Solar Biomass	5.16 6.83 13.25 13.67 17.30
Danish jobs - other green measures	Juul, Hansen, Hansen and Ege, 2009	2009	Denmark	Construction of fifteen biogas plants a year Construction of six new geothermal plants Construction of two new offshore wind farms and replacement of land-based wind turbines New central heat pumps Private heat pumps Construction of light railway in Copenhagen Expansion of bicycle path network and increased number of cyclists Mandatory service programme district heating customers Conversion of electrical heating	10.17 10.36 10.41 10.24 13.41 9.19 10.46 16.61 16.26
Solar thermal electricity in Spain	Caldes, Varela, Santamaria and Saez, 2009	2009	Spain	Parabolic trough plant Solar tower	10.31 5.90
Working for the climate	Greenpeace, 2009 (and authors' calc.)	2009	Worldwide	Business as usual scenario Energy [R]evolution scenario	24.47 23.04
				Average	15.56

Table A-2: Employment Effects for Clean Energy and other "Green" Activities

Resource	Reference	Year	Location	Intervention	Jobs/M€ invested
PERI - Military expenditures vs others	Pollin and Garrett-Peltier, 2009a	2007	U.S.A.	Military Tax cuts for personal consumption Health care Education Clean energy	12.20 14.53 19.19 28.51 16.72
PERI - Infrastructure investment	Heintz, Pollin and Garrett-Peltier, 2009	2008	U.S.A.	Baseline scenario High scenario - accelerated infrastructure investment	19.10 18.72
FHWA - Highway Infrastructure Investment	FHWA, 2010	2005 2007 2007	U.S.A.	Highway Infrastructure Investment Highway Infrastructure Investment (with purchase of right of way) Highway Infrastructure Investment (without purchase of right of way)	36.31 38.13 41.21
American Recovery and Reinvestment Act Fiscal Stimulus	Executive Office of the President, 2009	2009	U.S.A.	Government spending Tax cuts State fiscal relief	15.14 9.60 11.96
				Average	21.64

Table A-3: Employment Effects for various non energy related activities